NATIONAL ASSOCIATION

OF

CEMENT USERS

PROCEEDINGS

OF THE

FIFTH ANNUAL CONVENTION

Held at Cleveland, Ohio,

January 11, 12, 13, 14, 15, 16, 1909

VOLUME V

EDITED BY THE PRESIDENT

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LIST OF OFFICERS

OF

THE NATIONAL ASSOCIATION OF CEMENT USERS

1909.

PRESIDENT.

RICHARD L. HUMPHREY.

FIRST VICE-PRESIDENT.

MERRILL WATSON.

SECOND VICE-PRESIDENT.

M. S. DANIELS.

THIRD VICE-PRESIDENT.

E. S. LARNED.

FOURTH VICE-PRESIDENT.

GEORGE C. WALTERS.

SECRETARY.

GEORGE C. WRIGHT.

TREASURER.

H. C. TURNER.

SECTIONAL VICE-PRESIDENTS.

(See page 7.)

SECTIONAL COMMITTEES.

(The Chairmen are Vice-Presidents of the Association.)

ART AND ARCHITECTURE.

F. A. NORRIS, *Chairman.*

C. L. BORIE,
HOWARD CHAPMAN,
ALBERT MOYER,
THEODORE H. SKINNER.

BUILDING LAWS AND INSURANCE.

W. H. HAM, *Chairman.*

EDWARD D. BOYER,
JOHN E. CONZELMAN,
H. S. DOYLE,
EMILE G. PERROT.

CONCRETE AND REINFORCED CONCRETE.

A. E. LINDAU, *Chairman.*

SANFORD E. THOMPSON,
CHARLES M. SPOFFORD,
F. P. McKIBBEN,
A. N. TALBOT.

EXTERIOR TREATMENT OF CONCRETE SURFACES.

L. C. WASON, *Chairman.*

WM. N. HAZEN.
B. A. HOWES, JR.,
H. H. QUIMBY,
CHARLES D. WATSON.

MACHINERY AND APPLIANCES.

L. V. THAYER, *Chairman.*

A. T. BRADLEY,
O. U. MIRACLE,
H. H. RICE,
H. E. RACKLE.

ROADWAYS, SIDEWALKS AND FLOORS.

C. W. BOYNTON, *Chairman.*

H. B. ANDREWS,
A. C. BIRNIE,
W. W. SCHOULER,
A. E. SNODGRASS.

SPECIFICATIONS FOR CEMENT PRODUCTS.

W. P. ANDERSON, *Chairman.*

PETER GILLESPIE,
J. Y. JEWETT,
H. C. TURNER,
PERCY H. WILSON.

SPECIFICATIONS FOR FIREPROOFING.

R. P. MILLER, *Chairman.*

EDW. T. CAIRNS,
W. C. ROBINSON,
JOHN S. SEWELL,
IRA H. WOOLSON.

PAST OFFICERS.

President.	1905	JOHN P. GIVEN. (Resigned at close of first convention.)
	1905–8	RICHARD L. HUMPHREY.
First Vice-President.	1905	A. L. GOETZMANN.
	1906–8	MERRILL WATSON.
Second Vice-President.	1905–6	JOHN H. FELLOWS.
	1907–8	M. S. DANIELS.
Third Vice-President.	1905	H. C. QUINN.
	1906–7	O. U. MIRACLE.
	1908	S. B. NEWBERRY.
Fourth Vice-President.	1905–7	A. MONSTED.
	1908	GEORGE C. WALTERS.
Treasurer.	1905	A. S. J. GAMMON.
	1906–8	H. C. TURNER.
Secretary.	1905–6	CHARLES C. BROWN.
	1907	W. W. CURTIS.
	1908	GEORGE C. WRIGHT.

CHARTER

OF

THE NATIONAL ASSOCIATION OF CEMENT USERS.

KNOW ALL MEN BY THESE PRESENTS, That we, the undersigned, all of whom are citizens of the United States, and a majority of whom are residents of the District of Columbia, have associated ourselves together for the purpose hereinafter set forth and desiring that we may be incorporated as an Association under sub-chapter three (3) of the Incorporation Laws of the District of Columbia, as provided in the Code of Law of the District of Columbia, enacted by Congress and approved by the President of the United States, do hereby certify:

1. Name. The name of the proposed corporation is "The National Association of Cement Users."

2. Term of Existence. The existence of the said corporation shall be perpetual.

3. Objects. The particular business and objects of the said corporation shall be to disseminate information and experience upon and to promote the best methods to be employed in the various uses of cement by means of convention, the reading and discussion of papers upon materials of a cement nature and their uses, by social and friendly intercourse at such conventions, the exhibition and study of materials, machinery and methods and to circulate among its members by means of publications the information thus obtained.

4. Incorporators. The number of its managers for the first year shall be fifteen.

In Witness Whereof, we have hereunto set our hands and seals this fourteenth day of December, A. D. 1906.

RICHARD L. HUMPHREY, (SEAL)
JOHN STEPHEN SEWELL, (SEAL)
S. S. VOORHEES. (SEAL)

OFFICE OF RECORDER OF DEEDS,
DISTRICT OF COLUMBIA.

This is to certify that the foregoing is a true and verified copy of a Certificate of Incorporation, and of the whole of such Certificate as received for record in this office at 9:49 A. M., the 19th day of December, A. D. 1906.

In testimony whereof I have hereunto set my hand and affixed the seal of this office, this 20th day of December, A. D. 1906.

(Signed) R. W. DUTTON,
Deputy Recorder of Deeds,
District of Columbia.

(SEAL)

BY-LAWS

OF

THE NATIONAL ASSOCIATION OF CEMENT USERS.

ARTICLE I.

MEMBERS.

SECTION 1. Any company or persons engaged in the construction or maintenance of work in which cement is used, or qualified by business relations or practical experience to co-operate in the purposes of this Association, or engaged in the manufacture or sale of machinery or supplies for cement users, or a man who has attained eminence in the field of engineering, architecture or applied science, is eligible for membership.

SEC. 2. A company shall be treated as a single member and allowed but one vote.

SEC. 3. Any member contributing annually twenty or more dollars in addition to the regular dues shall be designated and listed as a Contributing Member.

SEC. 4. Application for membership shall be made to the Secretary on a form prescribed by the Executive Board. The Secretary shall submit monthly to each member of the Executive Board for letter ballot a list of all applications for membership on hand at that time with a statement of the qualifications, and a two-thirds majority of the members of the Executive Board shall be necessary to an election.

SEC. 5. Any member, after a fair hearing by first the Executive Board and then, with their approval, by this Association, shall be expelled from membership by a three-fourths ballot of the members present at any regular meeting of the Association, not less than twenty votes being cast. Such action shall not be publicly announced.

Article II.

OFFICERS.

Section 1. The officers shall be a President, four general Vice-Presidents, a Vice-President for each section into which the Association may be divided, a Secretary and a Treasurer.

Sec. 2. There shall be an Executive Committee of the Executive Board, consisting of the President, Secretary, Treasurer and two of its members, who shall be elected by the Executive Board.

Sec. 3. These officers, except the Secretary and Treasurer, shall be elected by ballot at the Annual Meeting and shall hold office for one year. The Secretary and Treasurer shall be elected annually by the Executive Board. Vacancies occurring during the year shall be filled by the Executive Board.

Sec. 4. The Executive Board shall consist of these officers and the five latest living Past-Presidents.

Sec. 5. The Secretary shall be custodian of the Association property and shall forward all moneys received to the Treasurer, obtaining his receipt for the same. He shall give such bond as the Executive Board may require.

Sec. 6. The Treasurer shall handle the funds of the Association subject to the approval of the Executive Board and shall give bond for the faithful performance of his duties in such sum as the Executive Board may designate. The Treasurer shall disburse funds only on warrant drawn by the Secretary and countersigned by the President.

Sec. 7. It shall be the duty of the Executive Board to audit the accounts of the Secretary and Treasurer before each annual meeting.

Sec. 8. The Secretary and Treasurer shall receive a salary to be fixed by the Executive Board.

Sec. 9. The Executive Committee shall manage the affairs of the Association during the interim between meetings of the Executive Board.

Sec. 10. The Association shall be divided into such sections as the Executive Board may determine by the enrollment of members of the Association in such sections as they may choose.

The Chairman of these sections shall be reported by the Committee on Nomination of Officers to the Association for election as Vice-Presidents of the Association, at the general election. Standing committees of four additional members each shall be appointed by the President of the Association in consultation with the respective chairmen to aid them in their work.

SEC. 11. At the first regular session of the Annual Convention, the President shall announce a committee on nomination of officers, and a committee on resolutions. These committees shall be appointed by the Executive Board.

SEC. 12. The election of officers shall take place at the business session on the second day of the convention, and they shall assume office at the close of the convention and hold same until their successors are elected and qualified.

ARTICLE III.

MEETINGS.

SECTION 1. The Association shall meet annually, the time and place being determined by the Executive Board, and notice shall be mailed to all members at least twenty days previous to the date of meeting.

SEC. 2. The Executive Board shall meet at least twice each year, the time and placed to be fixed by the Executive Committee.

ARTICLE IV.

DUES.

SECTION 1. The fiscal year shall commence on the first of January and all dues shall be payable in advance.

SEC. 2. The annual dues of each member shall be five dollars ($5.00).

SEC. 3. Any member whose dues shall remain unpaid for one year shall forfeit the privilege of membership. If he neglects to pay his dues within thirty days thereafter and after notification from the Secretary, his name may be stricken from the roll of membership by the Executive Board.

Article V.

STANDARD SPECIFICATIONS.

Section 1. Proposed Standard Specifications to be submitted to the Association must be mailed to the members at least thirty days prior to the Annual Convention, and as there amended and approved, passed to letter ballot, which shall be canvassed within sixty days thereafter, such specifications shall be considered adopted unless at least ten per cent. of the total membership shall vote in the negative.

Article VI.

AMENDMENTS.

Section 1. Proposed amendments to these By-Laws signed by at least three members, must be presented in writing to the Executive Board before November 1st of each year. In the notices for this meeting the proposed amendment shall be printed. At the annual meeting the proposed amendment may be discussed and amended and may be passed to letter ballot by a two-thirds vote of those present. If two-thirds of the votes obtained by letter ballot are in favor of the proposed amendment, it shall be adopted.

Sec. 2. The Executive Board is authorized to number the articles and sections of the By-Laws to correspond with any changes that may be made.

SUMMARY OF PROCEEDINGS OF THE FIFTH CONVENTION.

FIRST SESSION.—TUESDAY, JANUARY 12, 1909, 10.00 A. M.

The convention was called to order by the President, Mr. Richard L. Humphrey.

An address of welcome on behalf of the City of Cleveland was delivered by Dr. Harris Reed Cooley, Director of Charities and Correction, on behalf of Mayor Tom L. Johnson, as follows:

Gentlemen: I regret very much that Mayor Johnson is not able to be present in person this morning to welcome you to our city, but on his behalf and on behalf of the municipality I bid you a hearty welcome to Cleveland. I trust this is no formal matter. Cities have their spirit, their life, their social feeling, and I believe that hospitality is one of the characteristics of Cleveland. We welcome you for what you are doing for the world and for civilization.

As I visited the Exposition yesterday, and as I have studied somewhat of cement and concrete work, I have marveled at its rapid advancement, and yet I have a feeling that we are only at the beginning of a new era in construction; that we are but pioneers; it is extending in so many directions. Why, our cows are kept in concrete barns and eat out of concrete troughs and the milk is cooled in concrete cellars and our houses are concrete, we will walk upon concrete floors, sit by concrete fireplaces, perhaps eat off of cement tables. All through life we touch it, and then when we are dead we are buried in a concrete burial case, and the future generations know how good we were because it is carved upon a concrete tombstone. And there may be some agents enterprising enough to try to persuade St. Peter to put a concrete foundation under the golden pavement of the golden streets of the New Jerusalem. And some of these agents, when they go hence, may carry their samples with them and introduce reinforced concrete construction because of its wonderful properties in withstanding fire.

So you see, gentlemen, there seems to be no limit as to the possibility of the extension of this industry. We have purchased a great tract of two thousand acres for our institutions of charity and correction ten miles out from the city. The problem has been to build. It has been of the hollow-brick and reinforced concrete construction, using a great deal of cement. The result of the building is this: we have a central

building covering an acre of ground. Within this is a large court surrounded by a beautiful cloister with cement floor. In the center of the court is a magnificent fountain, and we could not have had that fountain were it not for concrete. This is our poorhouse, or, as we call it, the Farm Colony. A delegation of experts from Washington came to look upon it and they said to me, "It is marvelous how cheaply this building has been constructed. We know of no building of equal floor space that has been constructed for so small an amount." And yet some of my friends fear that we have too elegant a building out there, and they just recently expressed the belief that the building is too fine. It is by the power of building with concrete that we are able to make even our poorhouse a thing of beauty and permanence, fireproof, we trust also vermin-proof; floors of concrete and baseboards of concrete. We are building our workhouse at the present time, a mile and a half from this, with the same kind of construction. We are to have miles of sidewalk and I was intensely interested in your sidewalk discussion. I suppose we will have, when it is constructed, seven or eight miles of fence, and I have thought out the possibility of making the fence posts of concrete, and I find it is a very practical thing. And when we get out at the workhouse some expert in concrete making, cement working, we will put him not to drawing brushes—he may not be accustomed to that work—but we will set him to work making ornamental fence posts, that we may beautify our farm and make our surroundings more comfortable. I have in mind the construction of a concrete prison, with concrete cells, with walls that will be strong, that will be sanitary, that will be as joyful as possible, where we can hold our men and yet keep them in sanitary condition.

And so this question is really to me a very practical question, and it is a part of a very much larger one—the fact that the coming of cement and its products is bringing a new era to the building trade—possibilities of home construction. I suppose we will never have anything more graceful and beautiful than the Parthenon upon the Acropolis or than the temples where men worshipped in the palmiest days of the past. These buildings were for the gods and for the kings. We will say, "Cheapen these materials and we will soon develop the school of building that all these beautiful things and all these elegancies of the life shall come to the common people as well as to the king." I see the day coming when there will be greater abundance in this land of ours; not upon the one hand a million men seeking for a chance to work in this land of three million square miles of territory almost untouched, and on the other hand men receiving a hundred thousand dollars, yes, even five hundred thousand dollars a week as an income, which no man can possibly earn. When we shall stop giving privileges and great unearned incomes, and we shall demand that every man, for his own good as well as for society's good, shall give some useful service to the world, then there will be abundance; and then, with our inventions, then, with the use of these materials which

lie so common all about us, with human skill and human art, we will build every man a home where he can abide; and it will be said then, as it was formerly said only of the temples of the gods and the palaces of the kings, "Strength and beauty are in His sanctuary." It will apply to all.

We welcome you because you are bearing a part of this tremendous progress of civilization. We welcome you, not simply because of what you are doing, but because of what you are; for the architect is always greater than his building. The man who has constructed the great blocks of a city or built a palace is more than the things which his hands have made. We welcome you for the strength of manhood; we welcome you for the inventive genius; we welcome you for the knowledge and skill which your brain and hands have acquired, for the part which you will take in the great onward march of our civilization to the better days which are to come. We hope you will be well compensated for all that you shall do and that fortune may smile upon your labor; but more than your compensation in money, there ought to come to you the satisfaction that you are helping to a better time, when the people of this land and all lands shall live in better homes and better institutions; that those who are dependent and poor and unfortunate shall have better places in which to spend their declining years, and all life shall be better and happier because you are serving, because you are helping in this development of civilization and of progress.

We are glad you have come to Cleveland. Emerson has said in his essay on friendship that "Happy is the house that shelters a friend," and that when you have gone away from the city I am sure our municipality will be richer in thought and practical ability because of your presence in our midst. We trust that your deliberations may be filled with much of fellowship and profit to yourself and that you may bear with you when you go away kind and pleasant remembrances of our fair city by the lake. Again, on behalf of the Mayor and on behalf of the municipality of Cleveland, I extend to you the key and bid you a hearty welcome to our midst.

President Humphrey then responded:

I think this Association has been particularly fortunate in having so cordial a welcome extended by one thoroughly attuned to our work. It is certainly a good thing to have pointed out the higher purposes and duties of this Association. We should, I think, carry from each convention some aim higher than that we had when we arrived. So in accepting the welcome to the city of Cleveland which you, Dr. Cooley, have so warmly extended, I feel that we in turn should express our thanks and appreciation for your inspiring words which will serve as a standard for our next year's growth. On behalf of the Association I desire to express our appreciation of the welcome you have extended.

This Association stands primarily for progress, for progress in the development of the scientific art, if you will, in the proper use of cement. We have a very potent educational feature in the exploitation of its manifold uses, the power and functions of which have already been touched upon. We are fortunate in having with us and are honored by the presence of the president of one of the important educational institutions of this city, who has kindly consented to say a few words to us on behalf of the scientific institutions of the city of Cleveland. I take great pleasure in introducing to you Dr. Charles S. Howe, President of the Case School of Applied Science.

Address by Dr. Charles S. Howe:

Mr. President, on behalf of the scientific and technical institutions of Cleveland, it gives me great pleasure to extend to you a hearty welcome to our midst. We are interested in this question from a scientific and technical standpoint, because the product which you represent has been developed and improved by scientific men and is used by the engineer to a very great extent. There is a wider interest, however, than this, which we as citizens of Cleveland feel, because this subject is important historically; it is important in the life of to-day; it is one of the problems which we must study for the future. It is interesting historically because cement has been known for so many thousands of years. Every reader of the classic authors is impressed by the great monuments of which they treat, the great buildings which were constructed and which, in some cases at least, have lasted for so many years. A few of the writers of antiquity have shown us something about the building materials which were used in those ancient structures, and we find that cement of some kind entered into many of them. We could hardly expect, of course, that those ancient inventors, those ancient engineers and architects, would know the scientific aspects of the question as we know them to-day, but we are astonished to find that their work, without the aid of chemistry, and without the aid of the other sciences which we have to-day, has lasted as long as it has. That they did not have the benefits of scientific study and of scientific observation is shown by the fact that while some of their work remains and is still as hard and solid as ever, some of it has crumbled in the lapse of time.

If we trace the history of this subject down through the Middle Ages we find there, too, that in the great buildings, in the bridges, in the cathedrals and in many castles, cement was used and has lasted until the present time in a splendid state of preservation. But it was not until recent years, until, especially after a great deal of work had been done in the modern way by the science of chemistry, that the material which you are here to consider, and which you are using day by day, became one of the great building materials of the world. In the latter part of the eighteenth and during the early part of the nine-

teenth centuries cement, of course, was developed in a practical way in England and in a scientific way, especially in France. Our own country seems to have been very backward in doing any work along those lines until within recent years, for I believe Portland cement was not known in this country until after the close of the Civil War, and it was not manufactured here until some years later. As its value became more and better known large amounts were imported from abroad, because we could not supply it in sufficient quantities here. But the energy and enterprise of the American manufacturer and the American engineer have been applied to this subject, and the growth since that time in manufacture and, of course, in use has been enormous. If I remember the figures rightly—you gentlemen know them much better than I do—over $56,000,000 worth of cement was manufactured in the United States in the year 1907.

Now it becomes an important question when a product is turned out in amounts like this; it becomes an important question for all classes of people. It is important to the manufacturer, it is important to the citizen, it is important from an economic standpoint. It would be worth the while of any man to take a great deal of time to develop the importance of this subject along any of these lines. It is, of course, impossible for me to do so this morning. I shall refer to only one or two things, and in doing so I feel that you know far more about this subject than I do.

Building material, of course, is of different kinds. The material which persons can get at in the easiest way is the material which is first used for structures. It is evident, then, that crude rocks, that stones which could be picked up without any quarrying, were the first kind of building materials. As civilization advanced, as more became known about the use of tools, it was evident that the two materials, natural building materials, wood and stone, would be more and more used, because they could be cut into the requisite forms, and because they were found so widely scattered throughout the world.

Other forms of building material also came to be known as soon as people had learned to use the elements of science; bricks, tile, etc.; and perhaps last of all, cement. For it is only when the scientific aspects of this subject were studied that cement could become a great building material. While it was simply a material which somebody had found out could possibly be put together and a certain result obtained, it would have some use; but when the chemical processes came to be known and it could be reasoned out in advance that a certain course of manufacture would produce a certain result, then, of course, it could be made a most valuable material. We may guess at something for many years and obtain fair results; but we never obtain the best results in any kind of work by simply guessing. It is after the material itself, after the processes have been subjected to scientific treatment, and when we can determine in advance what we are going to get, that the greatest results will come. And it has been so

in the case of cement. That this is now and is going to be a great building material is absolutely certain. The properties which it possesses are enough to make it so. The fact that it can take the place of wood and is fireproof is one of the great reasons why it is to be the building material of the future. If our schoolhouses had been built of cement there would not have been some of the great disasters which have occurred to our schoolchildren. So far as I know, no great steps —I don't mean to say that not any steps, but no great steps—have been taken toward making schoolhouses of cement; and I for a number of years have been looking forward to the time when educational buildings would be constructed almost entirely of this material. And I believe that time will come, and especially with regard to school buildings where small children attend. The immense losses which come from fire every year are brought home to you as citizens as well as manufacturers.

The enormous amount of money that is put into building material is evident to any one who has given any attention to this subject. Over a billion dollars are put into building material every year—I understand that is somewhere near the present figure—and the losses by fire, direct and indirect, are five hundred millions. It is evident that here is a great economic loss—not a loss to one class of people or to another, but a loss to the whole country; because we cannot destroy any material without affecting more than the man who directly owns that which is destroyed. Destruction is loss of wealth. Wealth comes largely through labor, and if this is destroyed the whole country, of course, suffers to that extent.

But there is another reason why the material which you manufacture and which you use is important to the country at large, and that is because it is beginning to take the place of material which is reaching its end, a material the supply of which is being exhausted. The great Conservation Congress which was held in the White House last May, and the Conservation meetings which have been held since that time, have brought home to the people of the United States the fact that one of our great building materials, lumber, is rapidly being exhausted. It is true that no scientific census of the amount of standing timber in the United States has been made. It has not yet been possible to make such a census, but it is in process of being made. All we can do now is to estimate how much standing timber there is, and we can estimate very closely how much is being used. And it seems evident, from the statistics at hand, that the lumber supply of the United States will be exhausted in somewhere between twenty and thirty-five years. If one of our great building materials is going to be removed entirely from the field by that time, it is evident that something will take its place; and those who have given the most study to the subject are convinced that cement and concrete are the substances which are going to take, in a large degree, the

place of lumber. So that from this standpoint the use of cement and concrete is one of the greatest questions of the future.

Of course, I understand that you gentlemen are here in a business convention, that this subject to you is one of business. I think, for the reasons which I have stated, it is more than a question of business. I take it that you have here a great educational convention; that you are showing to the people of Cleveland and vicinity what can be done with this material; and I feel certain that the results will be advantageous to our community.

I said that this subject was interesting to the engineer. It is also interesting to the student of engineering; and as representing a technical college I feel personally a great interest in what you are doing. I want my students to attend your convention; I want them to learn all that they can of what you have done and what you propose to do, because it is a part of their education. A few years ago the courses in cement construction in technical schools were very short. A little work was done, but not very much. To-day the course in cement and concrete is one of the most important courses that we give to an engineer. And for all of these reasons, gentlemen, it gives me great pleasure to welcome you to the city of Cleveland. I hope your convention will be a satisfactory one to you, and I know it will be of great interest to this community.

President Humphrey responded as follows:

The encouraging words of Dr. Howe certainly lead us to hope that this convention, with its educational features, may be helpful to the city of Cleveland. We should feel grateful to Dr. Howe for directing our attention to the necessity for high standards which we should maintain. We are to a certain extent a business organization, but since the use of the material is in its infancy we are unquestionably a strong educational institution.

We wish to extend to Dr. Howe, his faculty and students a most cordial invitation to come and make themselves at home either at our convention or our exhibition. They can feel that they are honorary members of this Association. While we are in the city we shall be glad to have them at our deliberations and our exhibition. I certainly voice the unanimous thanks of the Association to Dr. Howe for his words of welcome on behalf of the scientific interests of the city.

This convention is composed of men who are builders, creators of structures. Cleveland has the record of having one of the largest Builders' Exchanges in the country, and we are fortunate to have with us the president of this Exchange to welcome us on behalf of the building interests of the city; I have the pleasure of presenting to you Mr. George B. McMillan, President of the Cleveland Builders' Exchange.

Address by Mr. George B. McMillan:

It gives me great pleasure, indeed, to be with you this morning. It happens to be the first convention of this kind that I have ever had the privilege of attending. I enjoyed your discussion on the different methods of building sidewalks and of doing cement work in general. I feel sure that this meeting together of a body of skilled mechanics and builders, engineers and architects, cannot help but be of great benefit.

I extend to you on behalf of the Cleveland Builders' Exchange, which comprises a large percentage of the building industry of Cleveland, a hearty welcome. I might say on its behalf that it is a pleasure to have this body meet in Cleveland at this time and give us an opportunity to see your exhibition for the instruction of the builder and others interested in the use of cement.

I have had some experience with cement myself, and have aided in a small way in the construction of the great building for the poor of Cleveland made possible by the low cost of cement construction.

We all know that cement construction is in its infancy. It is only a short time, a few weeks ago, that we revised our building code permitting cement structures higher than six stories. I am glad to be able to report to this convention that while it was only about eight weeks ago that the revision was made, we have to-day a structure of eight stories of reinforced concrete; this was started October 8, 1908, and the eight stories were up and the outside walls practically completed on January 8. That is a pretty good record for cement. The building was partly erected before the building code was changed, so there is some discrepancy between the eight and the twelve weeks. The building was under construction—one or two stories up—at the time the code was changed, making it possible to build the eight stories.

So in that case you see what can be done with cement. A few years ago it would not have been thought possible to build such a structure of other than structural steel. Now we have an example of it right here, and if we can build an eight-story building and make it safe in every particular, there is no reason in the world that I can see why we cannot build one twenty stories. It is simply an engineering problem.

Dr. Howe has extended to you on behalf of the scientific institutions of Cleveland a hearty welcome, and Dr. Cooley, on behalf of the city, has extended the welcome of the municipality, and he has also given you the keys to the city. I want you to be a little careful, for the doctor said, you know, that they had no skilled cement workers at their institution, and I think possibly that is one reason why he wanted to extend the keys of the city to you. I know that he had the institution in mind of which he is director, and I only want to warn you gentlemen. Again, on behalf of the building industry of Cleveland, I extend to you all a hearty welcome.

President Humphrey responded:

I am quite sure, Mr. McMillan, that the Association feels grateful to you for your welcome on behalf of the building interests of this city, and expresses the hope to you that this convention will be helpful to that interest in furthering the use of this important material. We hope that the members of your Exchange will be with us during the time that we are here, that we may get better acquainted. On behalf of the Association I thank you for your welcome.

The President announced the appointment of the following committees:

Committee on Nomination of Officers:

Edward D. Boyer, Chairman, Catasauqua, Pa.
John E. Conzelman, St. Louis, Mo.
O. U. Miracle, Minneapolis, Minn.
B. H. Rader, Pittsburgh, Pa.
George Taylor, Boston, Mass.

Committee on Resolutions:

W. C. Boynton, Chairman, Detroit, Mich.
Emile G. Perrot, Philadelphia, Pa.
J. P. H. Perry, New York, N. Y.
F. D. Leslie, Cleveland. Ohio.
J. B. Foote. Chicago, Ill.

Mr. C. W. Boynton then opened a discussion on the Standard Specifications for Portland Cement Sidewalks.

The meeting then adjourned until 8 P. M.

SECOND SESSION.—TUESDAY, JANUARY 12, 1909, 8 P. M.

President Richard L. Humphrey in the chair.

The President announced on behalf of the Executive Board the following sections for the current year:

Art and Architecture.
Building Laws and Insurance.
Concrete and Reinforced Concrete.
Exterior Treatment of Concrete Surfaces.
Machinery and Appliances.
Roadways, Sidewalks and Floors.
Specifications for Cement Products.
Specifications for Fireproofing.

Vice-President Merrill Watson then took the chair.

The President delivered his annual address.

The following papers were read and discussed:

"Cost of Reinforced Concrete Construction as Applied to Buildings," Leonard C. Wason.

"The Availability of Concrete for Bridges—Its Cost and Durability," H. H. Quimby. In the absence of the author this paper was read by the President.

The meeting then adjourned until Wednesday at 10.00 A. M.

WEDNESDAY, JANUARY 13, 1909, 9.00 A. M.

Meeting of Section on Testing Cement and Cement Products, and Section on Insurance, Laws and Ordinances.

President Richard L. Humphrey in the chair.

The session was devoted to topical discussion on the manufacture of concrete blocks and the fire resistive properties of concrete buildings as effecting insurance rates. The question of proper building laws and ordinances was thoroughly discussed.

THIRD SESSION.—WEDNESDAY, JANUARY 13, 1909, 10.00 A. M.

President Richard L. Humphrey in the chair.

Reports were presented and discussed, as follows:

Report of Committee on Testing Cement and Cement Products, E. S. Larned, Chairman, was presented by W. A. Aiken, a member of the Committee. The following revision of paragraph 17 of the Standard Specifications for Cement Hollow Building Blocks was suggested by the Committee:

17. *Hollow Space.*—The hollow space in building blocks used in bearing walls shall not exceed the percentage given in the following table for different height walls, except where blocks containing a greater percentage shall be proven by actual test to meet all the requirements herein specified to the satisfaction of the bureau of building inspection, and in no case shall the walls or webs of the block be less in thickness than one-fourth their height.

The amendment offered by Mr. J. A. Smith "that the web of blocks 8 inches high and not over 16 inches long be not less

than 1¾ inches, provided that the required strength under this specification be secured," was referred to the Committee with instructions to report later.

Report of Committee on Cement Products and Machinery, A. T. Bradley, Chairman, was approved as read.

The President announced the following Committee on Awards for the most effective, attractive and artistic exhibit:

Dr. Charles S. Howe, President, Case School of Applied Science.

F. N. Hopkinson, Chairman, Cleveland Chapter, American Institution of Architects.

Charles B. McMillan, President, Cleveland Builders' Exchange.

Report of the Executive Board and the minutes of the meetings of the Board were approved as read. The following amendments to the By-Laws proposed by the Executive Board were approved and ordered to letter ballot:

Amend Article I by inserting after Section 2 a new Section 3, and renumbering the remaining sections.

SECTION 3. Any person contributing annually twenty or more dollars in addition to the regular dues shall be designated and listed as a Contributing Member.

Amend Article I (old Section 3), by striking out all after the first sentence and inserting the following:

The Secretary shall submit monthly to each member of the Executive Board for letter ballot a list of all applications for membership on hand at that time with a statement of the qualifications, and a two-thirds majority of the members of the Executive Board shall be necessary to an election.

The following proposed amendment to the By-Laws was referred back to the Executive Board for revision and presentation at a later session:

Insert after Article IV a new Article V, as follows:

SECTION I.—Proposed Standard Specifications shall be submitted at the Annual Convention by a Sectional Committee, and as amended and

approved, passed to letter ballot which shall be canvassed within sixty days thereafter. Such specifications shall be considered adopted unless a majority of the total membership shall vote in the negative.

Renumber Article V.

The Committee on Publicity, P. Austin Tomes, Chairman, made a report as to its work, which was approved.

The question of the place for the next Convention was considered. An invitation was extended on behalf of Atlantic City by Mr. George S. Lenhart, and communications were read from Toledo, Ohio; Columbus, Ohio, and Atlanta, Ga. The final selection of the place for the next Convention, under the By-Laws, will be made by the Executive Board.

The Committee on Nomination of Officers, Edward D. Boyer, Chairman, made the following report:

President, Richard L. Humphrey, Philadelphia, Pa.
Vice-President, Merrill Watson, New York, N. Y.
Second Vice-President, M. S. Daniels, Suffern, N. Y.
Third Vice-President, E. S. Larned, Boston, Mass.
Fourth Vice-President, George C. Walters, Atlanta, Ga.
Sectional Vice-Presidents:
- Art and Architecture—Leonard C. Wason, Boston, Mass.
- Machinery and Appliances—L. V. Thayer, Minneapolis, Minn.
- Exterior Treatment of Concrete Surfaces—Sanford E. Thompson, Newton Highlands, Mass.
- Roadways, Sidewalks and Floors—C. W. Boynton, Chicago, Ill.
- Specifications for Cement Products—W. P. Anderson, Cincinnati, Ohio.
- Specifications for Fireproofing—Rudolph P. Miller, New York, N. Y.
- Concrete and Reinforced Concrete—A. E. Lindau, St. Louis, Mo.

The officers thus nominated were unanimously elected, the Secretary casting the ballot.

The meeting then adjourned until 2 P. M.

FOURTH SESSION.—WEDNESDAY, JANUARY 13, 1909, 2.00 P. M.

President Richard L. Humphrey in the chair.

Mr. J. H. Chubb read a paper on "Cost and Value of Concrete Roads," which was followed by a discussion.

The report of the Committee on Streets, Sidewalks and Floors was then read by the Chairman, Mr. W. W. Schouler, presenting,

(*a*) Revision of Standard Specifications for Portland Cement Sidewalks.

This was discussed, revised and approved for letter ballot.

(*b*) Proposed Specifications for Concrete Roads.

These specifications were referred back to the Committee, with instructions to report at the next Convention.

The meeting then adjourned until 8 P. M.

FIFTH SESSION, WEDNESDAY, JANUARY 13, 1909, 8.00 P. M.

President Richard L. Humphrey in the chair.

The report of the Committee on Art and Architecture was presented by Mr. Albert Moyer, Secretary, in the absence of the Chairman, Mr. Charles D. Watson. This report was approved.

The Committee on Awards for the most effective, artistic and attractive exhibit reported as follows:

FIRST PRIZE.

Ideal Concrete Machinery Company, South Bend, Ind.

SECOND PRIZE.

The George H. Rackle and Sons Company, Cleveland, Ohio.

THIRD PRIZE.

American Hydraulic Stone Company, Denver, Colo.

FOURTH PRIZE.

Hayden Automatic Block Machine Company, Columbus, Ohio.

HONORABLE MENTION.

Atlas Portland Cement Company, New York, N. Y.
American Cement Company, Philadelphia, Pa.
Sandusky Portland Cement Company, Sandusky, Ohio.
Ransome Concrete Machinery Company, Dunellen, N. J.
Miracle Pressed Stone Company, Minneapolis, Minn.

The following papers were then read and discussed:

"Decorative Concrete Stone," Frederick A. Norris.

"Unburnable Homes and their Architectural Possibilities," Benjamin A. Howes, Jr.

"Small Concrete Houses—Manufacture and Cost," R. C. Knapp.

"Monolithic Concrete Wall Buildings—Methods, Construction and Cost," Robert H. Aiken. In the absence of the author, this paper was presented by Mr. W. S. Abbott.

The meeting then adjourned until Thursday at 10 A. M.

THURSDAY, JANUARY 14, 1909, 9.00 A. M.

Meeting of the Section on Reinforced Concrete.

President Richard L. Humphrey in the chair.

This meeting was devoted to a topical discussion on the various applications of concrete construction.

SIXTH SESSION, THURSDAY, JANUARY 14, 1909, 10.00 A. M.

President Richard L. Humphrey in the chair.

President Humphrey presented on behalf of the Executive Board the revised By-Laws covering the adoption of Standard Specifications as instructed by the Convention, as follows:

Insert after Article IV a new Article V as follows:

SECTION I.—Proposed Standard Specifications to be submitted to the Association must be mailed to the members at least thirty days prior to the Annual Convention, and as amended and approved, passed to letter ballot which shall be canvassed within sixty days thereafter, such specifications shall be considered adopted unless at least ten per cent. of the total membership shall vote in the negative.

This amendment was discussed and approved for letter ballot.

The following papers were then read and discussed:

"Advantage of Reinforced Concrete for Railroad Construction," B. H. Davis.

"The Applicability and Comparative Cost of Concrete and Reinforced Concrete for Subway Construction," Charles M. Mills.

"Value and Cost of Reinforced Concrete for Retaining Walls," A. E. Lindau.

The meeting then adjourned until 8 P. M.

SEVENTH SESSION—THURSDAY, JANUARY 14, 1909, 8.00 P. M.

President Richard L. Humphrey in the chair.

The Committee on Streets, Sidewalks and Floors reported on the revised form of Standard Specifications for Portland Cement Sidewalks, as instructed, which was after discussion approved for letter ballot.

The Committee on Testing Cement and Cement Products reported as instructed, and its report was approved.

Paper by Mr. Emile G. Perrot on "Comparative Cost of Reinforced Concrete Buildings" was then presented and discussed.

A paper on "Evolution of Concrete Reinforcement" was read by Mr. H. F. Porter.

The meeting then adjourned until Friday at 10 A.M.

FRIDAY, JANUARY 15, 1909, 9.00 A. M.

Meeting of Section on Cement Products and Machinery, Mr. A. T. Bradley in the chair.

The session was devoted to a general discussion on the manufacture and applicability of concrete blocks.

EIGHTH SESSION.—FRIDAY, JANUARY 15, 1909, 10.00 A. M.

President Richard L. Humphrey in the chair.

Mr. William M. Bailey read a paper on "Methods of Attaching Shafting and Machinery in Reinforced Concrete Buildings."

Mr. Sanford E. Thompson, Chairman, presented the report of the Committee on Reinforced Concrete, which was approved as printed, and it was ordered that the report be printed and sent out to the members for discussion, to be incorporated in the Proceedings.

The report of the Committee on Insurance, Laws and Ordinances was presented in two parts. In the absence of Mr. William H. Ham, Chairman, Mr. Edward D. Boyer read Part I, the report on Insurance, which was approved as presented and ordered printed for distribution. Part II, the report on Laws and Ordinances, was presented by Mr. Emile G. Perrot. After a lengthy discussion extending until 6 P. M., with a recess from 2 to 3 P. M., the report was considerably revised and at the evening session was approved for letter ballot.

The meeting adjourned until 7.30 P. M.

NINTH SESSION.—FRIDAY, JANUARY 15, 1909, 7.30 P. M.

President Richard L. Humphrey in the chair.

The proposed Standard Building Regulations for Reinforced Concrete, reported by the Committee on Insurance, Laws and Ordinances, as finally revised was approved for letter ballot.

The following papers were read and discussed:

"Fireproofing with Concrete—Its Suitability and Comparative Cost," Ross F. Tucker. In the absence of the author, this paper was read by Mr. J. A. Smith.

"Progress in the Use of Metal Forms, with Comparative Cost," W. L. Caldwell.

"Cold Storage Warehouses of Reinforced Concrete Construction," J. P. H. Perry.

"Concrete Piles—Forms, Advantages and Cost as Compared with Wooden Piles," C. W. Gaylord.

"Value and Cost of Steam Curing of Concrete Blocks," F. S. Phipps.

"The Present and Future of the Cement Block—Its Cost, Manufacture and Availability," J. Augustine Smith.

"Waterproofing—Various Applications and Comparative Cost," T. Hugh Boorman.

Mr. Walter C. Boynton, Chairman, then presented the Report of the Committee on Resolutions, as follows:

Resolved, That the thanks of this Association be and are hereby tendered to the officials and other citizens of the City of Cleveland for their hearty welcome and courteous hospitality to the officers and members of the National Association of Cement Users, upon the occasion of the Fifth Annual Convention.

Resolved, That the thanks of this Association be and are hereby tendered to the Builders' Exchange and the chairman and members of the local committee of the City of Cleveland for their hearty co-operation in assuring the success of this Association's fifth annual convention and exhibition.

Resolved, That the thanks of this Association be and are hereby tendered to the exhibitors, the local press of the City of Cleveland and the technical press of the United States for the liberal support given both in advance and during the fifth annual convention and exhibition.

WHEREAS, This Association recognizes the great need of continuing the work of the Structural Materials Testing Laboratories of the United States Geological Survey, and highly appreciates the value of the country at large of the results obtained through the investigations at the laboratories, therefore be it

Resolved, That this Association as a body and through its members as individuals shall petition the Congress of the United States to provide an adequate appropriation for the purpose of continuing the work of the laboratories during the next fiscal year.

Resolved, That the thanks of this Association be and are hereby extended to the officers of the organization, whose faithful work and co-operation have made possible our decided progress in the past twelve months. This Association especially desires to record its appreciation of the work done in its behalf by its President, Richard L. Humphrey, to whose individual efforts a large share of our continued success is due. Be it further,

Resolved, That it is the sense of this Association that the President shall be fully reimbursed for his actual traveling, incidental and other expenses incurred in behalf of this Association, and that a sum of money sufficient to cover these expenses be appropriated from the funds of this Association, provided that said funds shall be sufficient to permit this to be done.

Resolved, That the thanks of this Association be and are hereby extended to the men whose contributions to our program have made the fifth annual convention of the highest interest to everyone in attendance.

The resolutions were unanimously approved as presented.

The President thereupon declared the Convention adjourned *sine die.*

National Association of Cement Users.

PROCEEDINGS

OF THE

FIFTH CONVENTION

This Association is not responsible, as a body, for the statements and opinions advanced in its publications.

THE PROGRESS OF THE ASSOCIATION AND THE NECESSITY FOR FIREPROOF CONSTRUCTION.

Annual Address by the President,
Richard L. Humphrey, M. Am. Soc. C. E.*

In the year which has elapsed since I last had the pleasure of addressing you on subjects of vital importance to our Association, we find ourselves stronger and far better organized for the work of education on which we are engaged than at any time in our history. This has been a year of decided development and much progress.

Our membership has grown steadily and our annual conventions show each year an increasing appreciation of the value of membership in this Association. The members are now beginning for the first time to more thoroughly realize how helpful and invaluable has been the information which they have acquired at each annual convention, and openly express their thorough appreciation. There can be no doubt that the example which they set their competitors, who are not always members of this Association, does much to raise the standard of workmanship and of first-class construction.

* Consulting Engineer, Harrison Building, Philadelphia, Pa.

The opening of permanent headquarters has more than fulfilled expectations and has demonstrated conclusively the necessity and value of this step. The few months in which this has been accomplished has opened up a vista of future possibilities which augers much for our campaign of education as to the proper uses of cement.

The past year has been particularly fruitful in many things which will redound for the greatest good of the cement industry.

After many years of work, the Joint Committee on Concrete and Reinforced Concrete has agreed upon a preliminary report on rules for the use of these materials which will be presented at the annual meeting of the American Society of Civil Engineers on January 18th, at the annual meeting of the American Railway Engineering and Maintenance of Way Association in March, and The American Society for Testing Materials in June of this year.

Our own committee on Reinforced Concrete has also contributed its share and this Convention for the first time will receive a report on rules for the use of reinforced concrete, and what is perhaps of still greater importance, our Committee on Insurance, Laws and Ordinances will present for your consideration, standard building regulations for the use of this material. It is to be hoped that the Association will adopt standard regulations at this Convention, and these will undoubtedly do much to bring about an increasing use of this material. The report of the Committee on insurance rates seems almost like an endorsement of this material for building construction, particularly as it relates to structures having a high resistance to fire. These rates indicate clearly that buildings of this class are being looked upon with increasing favor, so much so, that the owners of many buildings have reported that they did not deem it necessary to carry insurance, because of the fire resistive qualities of the material.

With the destruction of our forests, this country is turning to concrete as a desirable substitute and this is perhaps, indeed fortunate. In its mad rush toward a prosperity unparalleled in the history of civilization, this nation has permitted abuses which are as startling to the outside world, as has been our

advancement. Our priceless heritage of natural resources has been squandered with a prodigality that threatens exhaustion of many of them before the end of another century. The most serious is the depletion of our magnificent forests which have been slashed and cut with such a ruthless hand that unless drastic measures are at once taken to save what remains and strive to replace what we have already destroyed by the replanting of trees, our supply according to the opinion of the Federal Forest Service, will be exhausted in thirty-five years.

The greatest waste of timber is caused by fires, and the record of the United States is the most shameful of all the world. In 1907 the property destroyed by fire amounted to the enormous total of $215,000,000, a per capita loss of $2.51. Of this loss, $146,000,000 was in frame buildings and but $68,000,000 in brick and stone. This terrible waste is not equalled by any other nation. Our per capita loss is nearly eight times that of Europe, which is reported by the National Board of Fire Underwriters as but 33 cents for the six largest countries. Under similar conditions, the fire loss in this country for 1907 would have been but $27,000,000, and $187,000,000 would have thus been saved. Nor is this all. The United States has the finest and most efficient fire fighting apparatus and private fire protection in the world. Eliminating the loss of property destroyed in fires, the cost of fire protection for 1907 amounted to $241,401,442. There was paid to insurance companies in excess of what they returned as losses, $145,000,000. The fire departments cost fully $50,000,000 and private protection systems $18,000,000. Altogether the total cost of fires in the United States during 1907 amounted to $456,486,151, or $5.34 per capita, nearly one-half of the cost of new building construction for the same year, estimated at $1,000,000,000.

Confronted by such startling figures, we naturally look for the cause, and it is easy to find. This country is filled with buildings so faultily and flimsily constructed, that they are a constant menace. In our large cities are thousands of fire traps, any of which may at any time cause a conflagration that would wipe out millions of dollars worth of property and destroy the lives of many people. Our villages and hamlets are for the most

part a collection of fire traps. In many instances our theatres and assemblage halls are on the upper floors of frame buildings. It is a crime against humanity to permit public assemblages above the first floor in any building that is not fireproof. It is a crime to have a public meeting place in any building that is not fireproof. The sooner the authorities are brought to such a realization of this fact as will lead to the adoption of adequate laws and their rigid enforcement, the sooner will these terrible holocausts cease.

The people of Cleveland have had one fearful lesson in the past year by the burning of the Collinwood school house, in which the lives of more than 150 little children were lost. While this may be charged to bad construction, those responsible for the conditions which permit such structures to exist and to be occupied for such purposes should be criminally liable. One year ago another frightful object lesson was recorded in the fire which destroyed the Boyertown, Pa., opera house, and resulted in the death of nearly 200 women and children, who were unable to escape.

Instead of profiting by these awful experiences, as would naturally be supposed, the country, after the horror of a disaster has ceased to attract attention, lapses into an indifference from which it can only be moved, by another similar disaster. Scattered all over the country, are Collinwood school houses and Boyertown opera houses, and these disasters will recur until these buildings are removed and our methods of construction are changed.

Numerous buildings are erected in congested centers of population in many parts of this country in which the term "fireproof" is applied under the building laws. Their occupants enjoy a false sense of security which leads them to relax or disregard the simple precautions so necessary for their safety. In 1906, according to the census authorities, more than 6,000 persons died from burns in this country.

Deplorable as is the needless and criminal loss of life in fires, there is another phase of the question that is most serious, the enormous drain on our natural resources, resulting from the annual destruction of millions of dollars worth of property

by fire, which is not possible under European standards. Last April a conflagration at Chelsea, Mass., resulted in an insurance loss of more than $8,000,000. Such conflagrations are possible in practically every large city in the country. The fire marshal of Ohio, Mr. D. S. Creamer, states in his annual report for 1907, that a conflagration costing $300,000,000 is entirely possible at any time in the city of Cleveland and in its sister city, Cincinnati.

It is the construction of flimsy tinder boxes, which are not tolerated abroad, that are responsible for our excessive annual losses from fire. This country is engaged in the mad race of building up structures that are almost as rapidly destroyed, and the losses which reach such tremendous figures, are preventable. These conditions are often attributed to a desire on the part of property owners to erect their buildings as cheaply as possible in order to obtain the highest return from their investment. While this may be true in some cases, I think the real reason is that we have not as yet outgrown our primitive conditions which necessarily prevail in newly settled countries. This country has been growing in population at an enormous rate and as this density of population increases, we are forced to adopt laws covering building construction at such centers, as will properly safeguard the people. These laws result from necessity and the people themselves exert a most potent influence in their adoption. Proper, conservative and safe building laws are the result of years of experience and that is why Europe shows up to such advantage in comparison with this country.

While our building knowledge has hardly developed into a science, we are learning rapidly the methods and materials necessary to secure the safety desired. The American people are not slow in adopting improvements when once their value is established. In the last few years, we have made wonderful strides toward better construction, under the helpful guidance of the U. S. Government. For many years the Federal officials have realized the seriousness of these conditions and the lack of knowledge concerning the properties of building materials. With the Government spending $40,000,000 annually in the construction of public works, it was found necessary to inaugurate

an elaborate series of experiments, in order that the money could be expended wisely—for the Government does not insure its buildings, but rather strives to make them of the highest fire resistive type.

The task of finding out the best materials for such structures was assigned several years ago to the Technologic Branch of the U. S. Geological Survey under the direction of Dr. Joseph A. Holmes, expert in charge. These experiments have continued up to the present time and although they have been conducted primarily in behalf of the government, the results have been given freely to builders, engineers, architects and the public generally.

In the revision of the building laws of the country, the progress has been extremely slow for the reason that a certain inertia must be overcome in removing the prejudice against changing existing laws. The influence of various interests opposed to this revision for commercial reasons, has been another factor in preventing the adoption of better laws. Adequate laws are the first essential in bringing about conditions to prevent the big annual fire losses. Laws must be enacted that will not only regulate new construction, but that will invest in the building authorities the right to condemn structures whose very existence are a menace to public safety.

This is especially true in great cities like New York where the presence of innumerable fire traps is a constant danger, which unless eliminated may some day result in a conflagration that will sweep the city. Laws, no matter how perfect they may be, can be of no real value unless they are rigidly enforced. Many existing laws if enforced, would prevent the erection of dangerous structures.

The most potent influence in the attainment of buildings in which public safety is properly cared for lies with the people. If every one could be brought to a full realization of the dangers due to faulty construction, they would bring about a reform in methods that would result in permanent progress. It is the duty of the people to demand buildings of the highest fire resistive type, in which to live and work, in which their children may go to school, in which the sick and helpless may be cared for and in which the people may be amused.

The enormous losses of life and property by fire which are preventable is a subject which cannot be too widely exploited or too often repeated, to the end that the public may be brought to a thorough realization of just how great this danger is. If the public would refuse to make use of a building known to be a fire trap, they would apply an effective remedy.

This Association can perform no service of greater importance to the public than to keep up an incessant demand for safer construction, and cement is one of the materials at least that will play a very important rôle in the attainment of this end.

COST OF CONCRETE CONSTRUCTION AS APPLIED TO BUILDINGS.

By Leonard C. Wason*, M. Am. Soc. C. E.

The actual cost of various parts of building construction is information guarded with great care from every interested or curious eye outside of the firm, and often even from the trusted employee. It is information usually known only to the manager or owners of the construction company and kept by them under lock and key. The author proposes to give some actual job costs from his own experience, and it is not pure philanthropy on his part to publish this data. If the selfish business motive is stated, perhaps more confidence may be placed in the figures given.

Granolithic pavements have been so long in use and so many contractors have laid them that their cost is a matter of common knowledge, not only to all cement users but to the interested investing public. The result is that any contractor bidding a living profit above the actual cost of construction has a fair show of winning the job and the lowest bidder will usually make a profit. The same is true of building construction with brick and wood. Not so, however, is the case with concrete building construction. The art is now too new to have methods or even designs standardized sufficiently to permit of cost data being very generally known. A great many builders are taking up this type of construction at the present time, some who are competent, many who are not. The novices underestimate the cost and difficulties of doing good work, hence they bid unreasonably low, lose money and to some extent demoralize the true value of proper workmanship among architects, engineers and their clients. In the writer's opinion there is no class of construction where more painstaking skill and often technical knowledge is required than in reinforced concrete. When well done the resulting building gives satisfaction to the owner beyond that obtained from any other material, and when poorly done it is the least desirable, even

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if not actually dangerous. Concrete is either good or bad; there is no half-way state, and the difference in cost of materials to the builder between perfect and dangerous structures, is only five per cent. Therefore, there is likely to be injury done to a rapidly growing industry by novices either on account of ignorance, though coupled with honest, well meaning intent, or through skinning a job on which he is sure to lose money. Moreover, the older firms in the field have little to fear from the beginner, because so much depends on personal ability as well as experience. With growing competition improvements are constantly being made, and the standard of cost is not yet fixed but is being reduced steadily. The desire of reducing the present wild bidding and having only intelligent competition as well as saving some poor builder a loss he cannot afford, is the real inspiration of this paper. The author has undertaken it with the understanding that other competent writers will discuss it so that greater good results.

In order to have an intelligent understanding of the meaning of the figures hereinafter given, the method of collecting data will first be described. When making up an estimate of the cost of a building, in scaling the plans, it is found convenient to take off the volume of excavation and backfilling. The cubic feet of footings, foundation and wall, the square feet of forms for walls of foundations and above grade, the lineal feet of belt courses, mouldings, cornices, etc. Also the size of special features of exterior treatment. Similarly the superficial area of column and floor forms are measured by themselves. Concrete of each different mixture is scaled off in cubic feet and totaled separately. Steel of each kind is taken off in pounds. Granolithic finished surfaces in square feet and so on in detail every item is measured. As the work progresses it is desired to know weekly how the actual experience compares with the estimate and at completion to compile correctly the costs of each item to compare with estimate and to aid in obtaining the true cost of future structures of a similar kind. The method of accounting was developed to fit the estimate.

In the year 1898 daily time reports were designed having a number of columns for ease in sub-dividing the time of the workmen, Figs. 1 and 2. At the head of each column the timekeeper

puts index numbers or letters to show the kind of work being done, and below the actual time the men worked. On blank spaces at

JOB NO. 747 LOCATION Attleboro, Mass. ABERTHAW CONSTRUCTION CO., BOSTON
DATE Aug 17 1910 DAILY REPORT

Name of workman	Time Off'd	Time Meas'r	Time Mixer	Time Mixer	Time Mixer	Time Mixer	Time Mixer	Time Mixer	Time Coal'r	Time Mixer	OFFICE Rate	OFFICE Amt.		Put at head of proper column or against each name index of work performed
E. F. Claxby Foreman	9½										30—		5 25	State each kind of work done Amount of Conc. and Materials used
2 Maciatine	9½										15—		2 64	Weather
3 Cook, John	9½										.41		3 59	Temperature 7 A. M.
4 Angevine			5				4½				.37½	Meef	9 38	1 P. M.
5 Blanchard		7	2								"	Meer	4 43	1 P. M.
6 Cameron			9								.28	Meec	3 11	
7 Clough		7		2							.37½	Meef	3 27	
8 Cook, James		4				5					.41	Meer	9 02	
9 Dance					3	6					.37½	Mef	11 41	
10 Dupont		5	4								"	Meef	12 34	
11 Emmons			5				4				"	Ceer	3 88	Ceer = Motor Shaft
12 King			9								"	Mixer	3 51	
13 Lambert			4			5					"	Mixer	2 70	
14 Lemieux					3	1			5		.25	Water bbl	.30	Meef 630 c.f.
15 Lovejoy			9								.37½		.3244	Meer 46 - [6th]
16 O'Connell		6		3							"			" 11.6
17 O'Hara		6		3							41			" 21
18 Parcus		9									.28			
19 Peterson			9								.34			140 bags cement used
20 Poulx			9								37½			
21 Robarge		9									"			
22 Sanford			2								"			
23 Spittle			9								"			
24 Stevens			7							2	"			
25 Turnbull			2						7		"			
26 Valignette			8								"			
27 Riley							9	Mixer			.28			
28 Phelan									9½		.25			
29 Martin			3			6					.20			
30 Johnson			9								"			
31 Spencer			5				2	2			"			
32 Lawson								9½			.25			
33 Beaudoux								4½	5		.22½			
34 Runefuite hel	9										.05			
35 71			5					4½			.28			
36 651			5					4½			.20			
37 652			5				1½	3			"			
38 653			5				2	2½			"			
39 676						7	2½				"			
40 677			5				4½				"			
Work performed														Approved 11-30-5-08

FIG 1.—DAILY TIME REPORT SHEET

extreme right of the report the timekeeper inserts in writing the amount of each kind of work done and the amounts of the principal materials used. The experience of eight years has required no change whatever in the principles first adopted. The only

change in the forms has been to increase the number of vertical columns so that a larger number of sub-divisions can be used without troubling the timekeeper to re-write the names on another sheet. At the present time, ten vertical columns are used for recording time with the names of the workmen at the extreme left, two columns being left at the right for the rate per hour and the total amount. At the beginning of a job, written instructions are given as to how the work is to be sub-divided into items in the reports. A standard method of classification has been adopted as follows:

The principal sub-divisions are given a capital letter. Thus everything whatsoever relating to concrete masonry is given the index letter M, excavating of all kinds, including work incidental thereto, the letter D, all work connected with plant the letter P,

Name of workman	Time Mixing	Time	Time Roof	Time	Time	Time	Time	Time	Time	Time	Rate	Amt.
678			5		4½						20	
681					4½					5	"	
682		5			4½						"	
684		5				4½					"	
685		5				4½					"	
688		5				4½					"	
690		5	2		2½						"	
692		5				4½					"	
696		5				4½					"	
697						4					"	

FIG. 2.—BACK OF DAILY TIME REPORT SHEET.

and so on, there being only seven sub-divisions to indicate every building operation. To indicate the kind of work, vowels are used. Thus the vowels beginning with "a" all relate to form work, as: "a", centering complete; when done by separate operations "aa" is making, "ae" is setting, "ai" is straightening up or bracing, "ao" removing after being used, and "au" cleaning up and handling ready to be used again. All labor connected with mixing and placing concrete or with handling materials for same goes under the head of "e". All work in connection with plant, receiving, erecting, taking down, shipping and repairing is indicated by the vowel "i". Thus "i" means receiving and setting up plant ready to work, "ia" taking down, removing and shipping, and "ie" repairing. The consonants are used to indicate different parts of a structure in which certain work is done.

Under classification "M", "b" stands for footings, "c" columns, "d" foundations, "f" floors, "g" stairs, etc. Under classification "P", "f" stands for boiler, "g" for horizontal engine, "h" for vertical hoisting engine, "l" for elevator, "m" for mixer, etc. Thus our timekeeper places at the head of a column when he is reporting concrete floors, for the placing of forms "Maaf", for concrete "Meaf." If a mixer is being set up ready to work the report would read "Pim" and later if it was repaired it would be reported under "Piem," etc. This is not so complicated to use

Job. No. 747 — Aberthaw Construction Co.
Date May 24, 1906 — Mill. Tappan Bros. Attleboro. Mass.

		Proposal	Actual Cost	Unit Cost	Profit	Loss	o/o
Total		35164 55	31330 48	C.f.	3834 07		11
Excavate		790	823 18	.021		.33 18	
Footings & Foundation		1738	1033 57	.137	704 43		
Exterior Walls		1955	2162 02	.310		207 02	
Wall & F.n Centers		1520	3630 08	per 128		2110 08	
Floors Av 6¾" thick	Centers / Concrete	8883	6544 16	.097 / .342	c.f 2338 84		
Roof " 5¼" "	Centers / Concrete	2869	1713 51	.090 / .407	c.f 1155 49		
Columns 20"x20"		832	676 65	lin ft 1.47	155 35		
Stairs		883	910 35	.912		27 35	
Tool Surface		469	636 53	.056		167 53	
Ornaments & Cornice		348	164 33		183 67		
Ventilators on Roof		44	35 64		8 36		
Set Window & Door	Frames	852	729 99	each 2.19	122 01		

FIG. 3.—MASTER CARD NO. I.

as it may appear to read, and experience has proved that every man who knows enough to keep time can use the system with a few days experience. The principle is to make the least amount of clerical work for the timekeeper on the job, as they have plenty of other work to do. In addition to subdivision of time as above set forth, it is the duty of the timekeeper to report the number of barrels of cement mixed in a day, which is usually done by the man in charge of the mixer counting the empty bags, and in addition the actual volume of concrete measured in place. From this, knowing the proportions, it is a very simple matter to obtain the amount of sand and stone used, and also to see if the right amount

of cement is being used. Carpenter work on forms is reported by the number of square feet of surface in contact with the concrete erected. Thus walls are measured two sides without deducting doors and windows, as it is usual to let the form work run straight across these unless it is impossible on account of mouldings, in which case the framing of the opening will cost as much as the form work omitted. Beam floors are measured around the perimeter of the beam and the flat surface of the panel and around the perimeter girders. No deduction is made for

Job. No. 747. ○ Itemized Costs.

	Stairs Centers		Screeds		2" Plank		7/8 Maple			Quantities
	Total-per lin			per Mbf		per Mbf		per Mbf		Screeds 16 Mbd ft
	$		$		$		$			
Labor Carp	368.71	369	346.94	21.68	328.60	7.64	564.13	28.21		2" Plank 43 "
Lumber	50.70	051	488.18	30.49	1059.08	24.61	936.64	46.93		
Nails	2.43	003			45.00	1.05	37.61	1.88		7/8 Maple 20 "
		423		52.17		33.30		7702		
Prepare to floor							248.30	12.42		Interior Partitions
								8944		8745 ft
	Concrete									
										Hard Pine for
	Total-per lin ft									Shafting Support
										6548 b ft
Labor Common	229.48	.236								
" General	45.42	045								
Cement	83.82	084								
Aggregate	34.61	035								
Steel	82.99	083								
Teams & Misc	12.25	012								
		489								

FIG. 4.—BACK OF MASTER CARD NO. I.

the loss of area by the intersection of beams and girders, and small openings in the floor are not deducted. Anything as large as an elevator or stairway is usually deducted. Form work for columns is measured for entire area of surface contact between wood and cement, all four sides. These reports are made out on the job daily and sent to the office. The bookkeeper works these reports up into units of measurement, as cost of labor per cubic foot of concrete and number of cubic feet of concrete per barrel of cement, number of square feet of form work erected, etc., and from this it is easy to obtain the unit costs hereinafter given. The bookkeeper can take the reports of four or five jobs, employ-

ing in the aggregate five or six hundred men, and in a single day work up the complete report for a week's time, thus it will be seen that there is really little extra labor involved in the sub-dividing of reports into a useful form over merely reporting the time so that the payroll can be accurately made. The system employed has appeared of sufficient value to others to warrant its being briefly outlined in Gillette's hand book on cost data, pages 14, 15 and 19, and a description of it also appeared in Engineering-Contracting of March, 1906. Materials received on the job

Job No. 747 — Aberthaw Construction Co. — 2
Mill — Tappan Bros. Attleboro, Mass.

			Proposal		Actual Cost		Unit Cost	Profit		Loss		%
Interior Partitions			1770	25	1656	35	.189 ☐	113	90			
Bolts & Iron Work			253		257	06				4	06	
Stair Railing & Grill			387		654					267		
Screeds & Setting			1086		835	12	per M 82.17	250	88			
2" Spruce under Flooring			2839		1431	69	33.30	1407	31			
7/8" Maple finish "			1738		1788	88	.0944			50	88	
Shafting Support			379	50	533	19	98.89			153	69	
" Foundation			98		70	07		27	93			
Roofing & Conductors			1255		1026	06		228	94			
Paving			1009		647	54	.094 ☐	361	46			
Retaining Wall	centers concrete	☐ c.f.	429		316	90	.211 .175	112	10			
Painting			400		375			25				
Steel. Footings & Walls			300		218	91		81	09			

FIG. 5.—MASTER CARD NO. 2.

are reported on cards especially printed for the purpose, listing the principle materials which are reported, in order to save work of the timekeeper in reporting materials accurately. When a job is entirely completed and the ledger account is closed, a master card is worked out giving the complete history of the cost. On one side of the card are written the items which went into the original estimate, such as excavation, backfilling, footing, foundations, columns, floors, walls, stairs, etc., etc. In parallel columns is placed the actual amount of the estimate with the actual experience, reduced to cost units such as cubic feet, square feet of form work, etc., and the percentage of profit or loss between the esti-

mate and actual results. On the reverse side of the card the principal items are worked out more in detail. Thus form work is reduced to cost of labor, lumber and nails, wire or other sundries used in the forms per square foot of surface. It also includes all staging necessary for placing concrete. Concrete is itemized into the superintendent's general labor, labor of mixing and placing, cost of cement, sand, stone, miscellaneous expenses such as teaming, plant and other general items, reduced to cubic foot measurement, which makes the total cost of the concrete in

Foreman E. F. Clasby ◯ Itemized Costs.

	Exterior Wall & F'n Centers		Columns Centers		Floors Centers		Roof Centers		Work	1906		Quantities
	Total	per □'	Total	per □'	Total	per □'	Total	per □'	Begun	5	30	Excavate 39455 cf
	$		$		$		$		Finished	12	31	
Carpenters	2934 55	103	877 96	093	1803 39	063	545 76	060				Footings & Fn 7546 cf
Lumber	663 61	024	67 55	022	913 80	032	280 80	028				
Nails	31 72	001	3 24	001	43 80	002	13 45	002				Ext. Wall 22762 "
		128		116		037		090				7817 cf
												Floors 89796 "
	Concrete		Concrete		Concrete		Concrete					7750 cf
	Wall above gr.											Roof 9030 "
												2477 cf
	Total	cu ft.	Total	cu ft.	Total	cu ft.	Total	cu ft.				Columns 3000 "
Labor Common	979 38	125	137 68	110	536 51	069	191 32	077				1250 cf
" General	134 53	017	17 63	014	181 81	023	56 01	023				Retain Wall 1150 "
Cement	562 99	072	77 49	062	771 74	100	237 26	096				1117 cf
Aggregate	358 36	046	47 30	038	484 32	062	149 20	060				Paving 6880 "
Steel			30 60	024	1634 35	211	166 99	078				
Teaming & Misc	126 76	016	16 80	013	172 04	022	52 77	021				Stairs 998 lin ft
Plant	265 76	034	42 75	034	429 51	055	137 32	075				
		910		235		542		407				

FIG. 6.—BACK OF MASTER CARD NO. 2.

place in each division of the building itemized for ready reference when making up future estimates on work of a similar character. These forms are shown in Figs. 3-7.

It is well known that the cost of materials and labor in different parts of the country varies somewhat. Having the unit items all sub-divided as above, into their elementary parts, it is an easy matter after determining the cost of materials in any locality to make the exact corrections to the results obtained on a previous job. Similarly, when a difference in the rate per hour for wages is known, if the same efficiency is obtained from the men it is very easy to make a correction, or if the efficiency

varies, judgment must be applied to determine the correct rate to use. It has been the author's experience that although the rate of wages and cost of materials may vary somewhat in different parts of the country, the variations frequently offset one another so nearly that the sum total of the unit cost obtained in one place may be used in another, very seldom needing correction. For instance, within one month, after careful investigation, a bid was made up on a structure at San Juan, Porto Rico, using the same unit costs as for a building in Boston. In the report that is

Job: No. 747. Aberthaw Construction Co. 3
Mill. Tappan Bros. Attleboro, Mass.

	Proposal	Actual Cost	Profit	Loss	%
Plant, Freight, etc	1860	2271 73		411 73	
Bond	100	120		20	
Extras	77 80	67 97	9 83		

FIG. 7.—MASTER CARD NO. 3.

given, the costs relate to strictly first class material and workmanship in every case, as it has been the endeavor of the author to establish and maintain one standard for all work. Work has been done on all buildings included in the following tables under open shop conditions. Superintendents have received steady time, ranging from $28 to $60 per week; timekeepers get steady time, from $15 to $18 per week; common laborers almost invariably receive 20 cents per hour; the variation on certain jobs have run from 15 cents to 22½ cents per hour. The working day has been nine hours. Carpenters in Boston for the last two years have received 43¾ cents per hour, eight-hour day. In the country

districts and smaller cities carpenters usually receive 37½ cents per hour, the limit ranging from 28 to 43¾ cents. Steel setting has been done chiefly by laborers of better quality than the common sort, with prices ranging from 22½ to 25 cents per hour,

TABLE I.—COST OF CONCRETE COLUMNS.

Job No.	Location.	Forms per sq. ft. of Surface Contact.				Concrete per cu. ft.						
		Carpenter labor.	Lumber.	Nails and Wire.	Total.	Concrete labor.	General labor.	Cement.	Aggregate.	Team and Miscellaneous.	Plant.	Total.
865	Office Bldg., Portland, Me.....	.133	.039	.001	.173	.064	.004	.087	.084	.012	.022	.273
788	Coal Pocket, Lawrence, Mass.....	.057	.024	.001	.082	.166	.003	.073	.041	.008	.016	.307
762	Mill, Southbridge, Mass.....	.097	.082	.002	.181	.073	.056	.107	.035	.027	.030	.328
747	Mill, Attleboro, Mass.	.093	.022	.001	.116	.110	.014	.062	.038	.013	.034	.271
733	Mill, Southbridge, Mass.....	.080	.056	.001	.137	.108	.048	.100	.037	.013	.034	.340
732	Coal Pocket, Hartford, Conn.....	.098	.047	.002	.147	.089	.043	.069	.055	.017	.013	.286
731	Garage, Brookline, Mass.....	.071	.051	.002	.124	.070	.028	.072	.058	.041	.020	.289
685	Warehouse, Portland, Me.....	.118	.016	.001	.135	.087	.027	.087	.070	.039	.025	.335
499	Textile Mill, Lawrence, Mass.....	.061	.013	.001	.075	.095	.019	.109	.027	.018	.015	.283
	Highest	.133	.082	.002	.181	.166	.056	.109	.084	.041	.034	.340
	Lowest.....	.057	.013	.001	.075	.064	.003	.062	.027	.008	.013	.271
	Average of 9	.082	.036	.001	.130	.096	.027	.085	.040	.021	.023	.301

with limits of 20 to 28 cents. In the tables, superintendent, timekeeper, and water boy are included under the head of general labor as well as all common labor that cannot be classified.

Cement has cost from $1.30 to $2.25 per barrel with an average price of about $1.50. Broken stone, from $0.90 to $2.00

TABLE II.—COST OF BEAM FLOORS OF REINFORCED CONCRETE.

Job No.	Location.	Forms per sq. ft. of Surface Contact.				Concrete per cu. ft.						
		Carpenter labor.	Lumber.	Nails and Wire.	Total.	Concrete labor.	General labor.	Cement.	Aggregate.	Team and Miscellaneous.	Plant.	Total.
827	Power House, Greenfield	.165	.107	.003	.275	.143	.020	.109	.101	.008	.016	.397
809	Tar Well, Springfield	.064	.041	.002	.107	.076	.005	.026	.075	.013	.040	.335
804	Mill, Greenfield, Mass.	.106	.061	.004	.171	.077	.011	.109	.086	.007	.055	.345
796	Car Barn, Danbury, Conn.	.044	.051	.001	.096	.128	.013	.086	.071	.011	.010	.319
788	Coal Pocket, Lawrence, Mass.	.072	.039	.002	.113	.056	.004	.073	.041	.009	.019	.202
762	Mill, Southbridge, Mass.	.067	.062	.002	.131	.137	.029	.191	.051	.038	.014	460
747	Mill, Attleboro, Mass.	.062	.032	.002	.096	.071	.023	.098	.062	.021	.055	.330
744	Bridge, Plymouth, Mass.	.047	.050	.001	.098	.078	.019	.100	.040	.027	.010	.274
741	Garage, Newton, Mass.	.104	.033	.002	.134	.116	.020	.121	.084	.038	.010	.394
733	Mill, Southbridge, Mass.	.057	.051	.001	.109	.119	.027	.132	.037	.013	.034	.362
732	Coal Pocket, Hartford, Conn.	.060	.033	.001	.094	.047	.023	.081	.055	.017	.013	.236
731	Garage, Brookline, Mass.	.105	.038	.002	.145	.160	.032	.088	.058	.041	.020	.399
729	Filter, Lawrence, Mass.	.048	.032	.001	.081	.102	.016	.085	.054	.012	.032	.301
694	Storehouse, Chelsea, Mass.	.064	.043	.002	.109	.153	.035	.115	.068	.052	.020	.443
685	Warehouse, Portland, Me.	.037	.029	.001	.067	.186	.030	.096	.069	.043	.046	.470
614	Textile Mill, Lawrence, Mass.	.045	.042	.001	.088	.130	.013	.071	.037	.025	.010	.286
499	Textile Mill, Lawrence, Mass.	.053	.033	.001	.087	.116	.033	.104	.049	.035	.015	.442
471	Chapel, Portland, Me.	.053	.027	.002	.082	.100	.008	.127	.091	.041	.010	.377
	Highest.	.165	.107	.004	.275	.186	.035	.194	.101	.052	.055	.470
	Lowest.	.037	.027	.001	.067	.047	.004	.071	.037	.007	.010	.202
	Average of 18.	.070	.045	.002	.116	.111	.020	.106	.063	.025	.024	.354

a ton, average about $1.25. Sand, from 50 cents to $1.50 a cubic yard, with an average of $1.00. Gravel, including sand and stone mixed, about the same as sand. Lumber, chiefly spruce and hemlock, sometimes a little white or North Carolina pine, $18-$28 per thousand, average price about $22. Teams have almost always been $5 a day of nine hours. The variations in cost due to different mixtures of concrete can easily be allowed for by reference to the table on page 133 of Volume IV, of the Proceedings. In general would say that the standard mixture

TABLE III.—COST OF FLAT SLAB FLOORS.

Job No.	Location.	Forms per sq. ft. of Surface Contact.				Concrete per cu. ft.						
		Carpenter labor.	Lumber.	Nails and Wire.	Total.	Concrete labor.	General labor.	Cement.	Aggregate.	Team and Miscellaneous.	Plant.	Total.
865	Office Bldg., Portland, Me.....	.078	.039	.001	.118	.043	.004	.087	.084	.012	.022	.252
852	Fire Station, Weston, Mass.....	.067	.038	.003	.108	.103	.007	.092	.053	.026	.039	.320
727	Church, Boston, Mass.	.067	.037	.002	.106	.146	.017	.109	.072	.020	.010	.374
	Highest	.078	.039	.003	.118	.146	.017	.109	.084	.026	.039	.374
	Lowest.....	.067	.037	.001	.106	.043	.004	.087	.053	.012	.010	.252
	Average of 3	.071	.038	.002	.111	.097	.009	.096	.070	.019	.024	.315

for all floors has been either 1-3-6, or 1-2-4, if the floor is subjected to extremely heavy loads and service. Walls are mixed 1-3-6, an l columns usually 1-2-4; in some cases where they are very heavily loaded a richer mixture is used. As these mixtures are common to nearly all construction, the costs here given may be applied with little danger of error from neglecting the mixture on any work. Of course it can readily be understood that in the large number of jobs which have entered into the averages given, there being as many as eighteen in the case of beam floors, different methods of conducting the work have been used and many different foremen. Therefore, while the general

TABLE IV.—COST OF CONCRETE SLABS BETWEEN STEEL BEAMS.

Job No.	Location.	Forms per sq. ft. of Surface Contact.				Concrete per cu. ft.						
		Carpenter labor.	Lumber.	Nails and Wire	Total.	Concrete labor.	General labor.	Cement.	Aggregate.	Team and Miscellaneous.	Plant.	Total.
810	Bleachery, E. Hampton.....	.054	.027	.002	.083	.092	.007	.137	.073	.012	.046	.367
799	Machine Shop, Milton, Mass.	.087	.027	.003	.117	.090	.033	.114	.075	.016	.034	.362
792	Foundry, N. Britain, Conn.....	.078	.046	.002	.126	.095	.021	.076	.078	.004	.022	.296
778	Stable, Boston, Mass.	.064	.012	.001	.077	.101	.019	.129	.070	.020	.015	.354
774	Residence, Milton, Mass.....	.110	.071	.003	.184	.105	.048	.132	.080	.053	.010	.428
752	Power House, Pittsfield, Mass.....	.029	.030	.001	.060	.131	.008	.123	.068	.013	.010	.353
725	Laundry, Boston, Mass.....	.058	.024	.001	.083	.092	.021	.098	.089	.022	.010	.332
676	Prison, Portsmouth N. H.....	.068	.017	.001	.086	.073	.005	.208	.075	.006	.010	.377
652	Paper Mill, Mittineague...	.097	.071	.002	.170	.144	.033	.143	.062	.027	.010	.419
584	Power House, Quincy, Mass.....	.047	.025	.001	.073	.073	.021	.159	.085	.064	.020	.422
583	School, Waltham, Mass.....	.029	.028	.001	.058	.138	.009	.102	.078	.018	.015	.360
494	Foundry, Providence, R.I.	.028	.020	.001	049	.084	.012	.114	.026	.026	.010	.272
494	Foundry, Providence, R.I.	.043	.021	.001	.065	.111	.010	.128	.029	.029	.010	.317
	Highest.....	.110	.071	.003	.184	.144	.048	.208	.080	.064	.046	.428
	Lowest.....	.028	.012	.001	.049	.073	.005	.076	.026	.004	.010	.272
	Average of 13	.061	.032	002	.095	.102	.019	.128	.068	.024	.017	.359

average is doubtless safe for any work of an average character, some latitude may be allowed the judgment in determining whether any specific case is likely to be difficult, easy or average. The author has found quite a difference, for instance, in cost of identical work handled by different foremen, due to the personal equation of their painstaking, supervision and ability. The type of the construction has had little influence on the unit costs. The writer has had intimate knowledge of all the details of the various structures entering into the tables, and it is his opinion that the chief variation in costs has been due to the efficiency with which the superintendent has handled the work rather than to any local conditions.

In Tables I-VII only typical jobs are given, whose results are correctly known. The results of a number of jobs have been spoiled by a change of timekeeper during the progress of the work, the new man missing for a day or two the proper classification or some other such small matter. It appears to the author, moreover, that the results from a few typical jobs would be of more interest than a mass of figures from all kinds of work, some of which would be of no value. Enough are given for a fair average, except in the case of long span flat slab, which is, by comparison, a recent type of construction. The figures for the highest, lowest and average totals in all columns are taken from the vertical column in which they stand and have no relation to the other figures in their horizontal line.

The general averages of cost on form work per square foot of surface contact as given in Tables I-VII, recapitulated, are:

Columns	$0.13
Floors with reinforced concrete beams	.116
Flat floors without beams	.111
Short span slabs between steel beams including the fireproofing on the sides of the beams	.095
Walls exposed to view above ground	.128
Foundation walls	.103
Mass foundations	.093

These averages are believed to be higher than what is usually considered to be a fair cost by the majority of builders. It is upon the success of handling forms that good financial results depend.

TABLE V.—COST OF BUILDING WALLS ABOVE GRADE.

Job No.	Location.	Forms per sq. ft. of Surface Contact.				Concrete per cu. ft.						
		Carpenter labor.	Lumber.	Nails and Wire.	Total.	Concrete labor.	General labor.	Cement.	Aggregate.	Team and Miscellaneous.	Plant.	Total.
852	Fire Station, Weston, Mass.	.116	.038	.004	.158	.100	.007	.069	.053	.026	.039	294
804	Mill, Greenfield, Mass.	.062	.038	.002	102	.060	.011	.084	.086	.007	.055	.303
802	Water Works, Waltham, Mass.	.137	.024	.001	.162	.146	.007	.058	.057	.014	.047	.329
788	Coal Pocket, Lawrence, Mass.	.118	.056	.002	.176	.042	.004	.073	.043	.009	.019	.190
747	Mill, Attleboro, Mass.	.103	.024	.001	.128	.129	.018	.074	.048	.017	.043	.329
732	Coal Pocket, Hartford, Conn.	.096	.047	.002	.145	.118	.052	.097	.055	.017	.013	.350
729	Filter, Lawrence, Mass.	.046	.032	.001	.079	.046	.017	.083	.054	.012	.032	.244
704	Italian Garden, Weston, Mass.	.101	.073	.002	.176	.102	.008	.105	.081	.019	.010	.325
703	Stable, Beverly, Mass.	.099	.030	.002	.131	.078	.019	.071	.062	.018	.010	.258
680	Residence, N. Andover, Mass.	.078	.016	.001	.095	.096	.014	.046	.050	.008	.010	.174
648	Observatory, Milton, Mass.	.056	.038	.002	.096	.095	.012	.060	.187	.058	.005	.417
640	Office, Boston, Mass.	.105	.030	.002	.137	.096	.033	.066	.114	.066	.005	.380
638	Tunnel, Boston, Mass.	.112	.045	.005	.162	.126	.016	.066	.106	.077	.005	.330
621	Hospital, Waltham, Mass.	.058	.028	.001	.087	.089	.017	.034	.063	.023	.010	.236
536	Residence, Boston, Mass.	.108	.036	.001	.145	.110	.015	.077	.069	.026	.005	.446
515	Coal Pocket, Providence, R.I.	.087	.020	.001	.108	.052	.005	.102	.090	.015	.010	.274
500	Italian Garden, Brookline, Mass.	.064	.027	.001	.092	.048	.011	.080	.071	.019	.010	.239
	Highest.	.136	.073	.005	.176	.146	.052	.105	.187	.077	.055	.446
	Lowest.	.046	.016	.001	.079	.042	.004	.034	.043	.007	.005	.174
	Average of 17	.085	.036	.002	.128	.090	.016	.073	.076	.025	.019	.301

In regard to concrete, labor is the variable item which must be carefully considered. Anyone of intelligence can make an

TABLE VI.—COST OF FOUNDATION WALLS.

Job No.	Location.	Forms per sq. ft. of Surface Contact.				Concrete per cu. ft.						
		Carpenter labor.	Lumber.	Nails and Wire.	Total.	Concrete labor.	General labor.	Cement.	Aggregate.	Team and Miscellaneous.	Plant.	Total.
831	Filter, Warren, R. I..	.103	.048	.004	.155	.062	.037	.086	.068	.012	.031	.296
809	Tar Well, Springfield, Mass.....	.071	.031	.002	.104	.040	.015	.094	.075	.013	.040	.277
757	Tunnel, New Bedford, Mass.	.048	.045	.001	.094	.213	.019	.203	.092	.057	.015	.599
756	Filter, Exeter, N. H..	.124	.067	.002	.193	.064	.021	.071	.116	.034	.019	.325
729	Filter, Lawrence, Mass.	.058	.042	.001	.101	.046	.017	.083	.054	.012	.032	.244
708	Theatre Portland, Me.....	.081	.024	.003	.108	.112	.013	.073	.078	.003	.020	.303
685	Warehouse, Portland, Me.....	.053	.009	.001	.063	.040	.019	.060	.070	.029	.017	.235
673	Residence, N. Andover, Mass.	.047	.019	.001	.067	.108	.006	.082	.045	.015	.010	.266
641	Filter, Lawrence, Mass.	.048	.035	.002	.085	.055	.006	.039	.027	.011	.010	.148
637	Residence, N. Andover, Mass.	.065	.019	.001	.085	.087	.012	.072	.045	.013	.010	.239
633	Retaining Wall, Naugatuck, Conn.....	.134	.047	.001	.182	.097	.018	.056	.032	.022	.010	.235
621	Hospital, Waltham, Mass.....	.048	.028	.001	.077	.043	.019	.038	.063	.026	.010	.199
544	Greenhouse, Brookline, Mass.....	.032	.035	.001	.068	.051	.007	.078	.043	.013	.010	.202
543	Hotel, Brookline, Mass.....	.037	.018	.001	.056	.043	.002	.080	.054	.010	.010	.199
	Highest.....	.134	.048	.004	.193	.213	.037	.203	.116	.057	.040	.599
	Lowest.....	.032	.009	.001	.056	.040	.002	.038	.027	.003	.010	.148
	Average of 14	.068	.033	.002	.103	.076	.013	.080	.062	.019	.017	.269

estimate of the materials to be used, but note the average prices of labor per cubic foot:

Columns	$0.123
Beam floors	.131
Flat floors	.106
Floors between steel beams	.121
Walls	.106
Foundations	.091
Mass work in connection with buildings	.052

TABLE VII.—COST OF FOOTING AND MASS FOUNDATIONS

Job No.	Location.	Forms per sq. ft. of Surface Contact.				Concrete per cu. ft.						
		Carpenter labor.	Lumber.	Nails and Wire.	Total.	Concrete labor.	General labor.	Cement.	Aggregate.	Team and Miscellaneous.	Plant.	Total.
827	Power House, Greenfield	.119	.077	.002	.198	.065	.020	.098	.092	.008	.016	.299
824	Engine Foundation, Taunton, Mass.	.054	.025	.001	.080	.045	.002	.065	.048	.004	.017	.181
817	Head Gates, Shawmut, Me.	.071	.043	.003	.117	.033	.001	.074	.099	.003	.014	.224
815	Canal, Lowell, Mass.	.039	.025	.001	.065	.025	.011	.080	.078	.004	.042	.240
807	Foundation, Provincetown.	.069	.043	.002	.114	.030	.004	.073	.099	.011	.049	.275
783	Dam, Merrimack, N. H.	.066	.037	.003	.106	.081	.008	.090	.055	.008	.031	.273
598	Foundation, Boston, Mass.	.011	.006	.001	.018	.035	.004	.061	.072	.006	.010	.188
597	Engine Foundation, Boston, Mass.	.095	.039	.003	.137	.037	.013	.061	.084	.013	.015	.223
491	Gas Holder, Springfield.	.034	.031	.002	.067	.043	.001	.061	.068	.005	.010	.188
488	Foundation, Providence, R.I.	.016	.011	.001	.028	.051	.002	.047	.076	.010	.010	.196
	Highest.	.119	.077	.003	.198	.081	.020	.098	.099	.013	.049	.275
	Lowest.	.016	.006	.001	.018	.025	.001	.047	.043	.003	.010	.181
	Average of 10	.057	.034	.002	.093	.045	.007	.071	.077	.007	.021	.229

Not until the last item is a price obtained in experience which, according to the observation of the author, the majority expect to obtain in building work in general. Many men who have had wide experience in handling large quantities of concrete in mass have at times attempted a lighter type of construction, and have been greatly surprised at the large expense connected therewith. It has come to the notice of the author a number of times that men with this experience have added 50 to 100 per cent. to the cost of mass work and felt that they were

TABLE VIII.—COST OF REINFORCEMENT.

Job No.	Location.	Weight in Tons.	Cost of Handling.	Cost per Ton.
865	Office Building, Portland, Me.	324½	$5,115.32	$15.76
852	Fire Station, Weston, Mass.	8½	40.26	4.74
846	Mill, Chelsea, Mass.	65¼	548.81	8.41
843	Coal Bins, Dalton, Mass.	8½	61.75	7.26
830	Dam, Auburn, Me.	55	506.76	9.18
831	Filter, Warren, R. I.	19	103.59	5.40
816	Tank, Lincoln, Me.	8½	69.38	8.16
809	Tar Well, Springfield, Mass.	15½	59.21	3.82
807	Monument, Provincetown.	24½	136.84	5.58
804	Mill, Greenfield.	92¾	1,232.01	10.20
799	Machine Shop, Milton, Mass.	20¾	177.16	8.75
788	Coal Pocket, Lawrence, Mass.	28	461.16	16.47
762	Mill, Southbridge	53½	142.76	2.67
759	Mill, S. Windham, Me.	293	3,079.60	10.51
747	Mill, Attleboro, Mass.	49½	286.02	5.78
741	Garage, Newton, Mass.	20	86.55	4.33
733	Mill, Southbridge, Mass.	30	100.03	3.34
732	Coal Pocket, Hartford, Conn.	195	2,316 60	11.88
729	Filter, Lawrence, Mass.	44½	112.84	2.54
685	Warehouse, Portland, Me.	62	462.99	7.47
639	Standpipe, Attleboro, Mass.	199½	1,547.00	7.75
788	Highest			$16.47
729	Lowest			$2.54
	Average of 21			$8.52

amply covered for light structural work. The fallacy of this can be seen by a very recent experience. In building a dam across the Connecticut River about 5,500 cubic yards of concrete were placed. Cement and aggregates were received on a bridge abutment 26 feet above the river. Aggregates were dumped upon an inclined chute where they were to be washed, and from the end of the chute they fell into bins, from which they were drawn through measuring hoppers into a mixer and dumped from this into tram cars four feet above the water. The total expense for labor of washing, charging, mixing and dumping

into cars was only $0.12 per cubic yard, and for moving it in cars an average distance of 700 feet, dumping and placing was only $0.30 per cubic yard for labor, or a total cost of $0.0155 per cubic foot.

Table VIII on reinforcement omits entirely the first cost of the material. After it is received at the site of the work in the shape sold by the manufacturer, the prices cover the cost of fabricating into units for columns or beams, bending the stirrups, placing

FIG. 8.—MILL AT ATTLEBORO, MASS.

and all incidentals whatsoever prior to the actual embedding in concrete. In the case of the highest cost, a coal pocket, there was very limited storage space, 1¼ in. bars had to be bent diagonally so as to pass over the top of the support at columns, and numerous stirrups, all of which had to be made by hand. The job was too small to justify any mechanical arrangement for bending or for handling material. The next highest office building, Portland, Me., there was a sufficient amount to require

proper machinery. The hoops for columns were all welded. The vertical bars were all wired inside of these hoops. There was a mushroom head of bent and circular bars wired together at the top and great numbers of long bars of small section spread in all directions over the floor. The lowest price, Filter at Lawrence, was made entirely of straight bars placed loose, the only expense being cutting them in a hand shear to length and placing them.

In Figs. 3-7 is given an exact copy of a set of "master cards" which gives the complete financial history of the job when it is

FIG. 9.—INTERIOR VIEW OF MILL AT ATTLEBORO, MASS.

finally completed. Photographs of this particular building are given in Figs. 8 and 9, for aid in understanding the explanation. The first column, which is blank, is occasionally used for an estimate of the first cost, the proposal including the profit as well as the estimated actual cost. It will be seen that on some items a loss was incurred, as well as a profit on others, showing that it is difficult, even on work which a company is fairly experienced on, to reach the right price on everything, and also that when slight changes are made by the owner or architect they often entail heavy loss even though the changes appear to be extremely

trivial. Take the case of the external walls. The owners furnished the window frames and sash, which were all of metal. The original design was for a frame with two sash, which could easily be put into a six inch wall. They later decided, for greater fire protection, to use four sash. This required an eight inch wall instead of six inch, and as will be seen in the picture, the form work on the inside is no longer a plane surface as the space under the windows was paneled to save material. To save making a very narrow panel at the side of the window, which would cost more than the concrete saved, the space was filled up solid so that the columns are wider than they were actually figured. From this slight change, which did not appear great at the time, it

TABLE IX.—COST OF COMPLETED FIREPROOF BUILDINGS.

Job No.	Location.	Job Cost.	Volume in cu. ft.	Floorarea in sq. ft.	Unit Cost.	
					Per cu. ft.	Per sq. ft.
865	Offices and Stores, Portland.....	$181,194	1,365,830	90,474	$.133	$2.00
862	Offices and Stores, Everett.	61,646	496,780	39,840	.124	1.545
804	Factory, Greenfield.....	12,774	112,440	7,519	.114	1.70
762	Factory, Southbridge.....	44,652	746,674	49,546	.060	.902
747	Factory, Attleboro.....	30,830	312,000	24,060	.127	1.60
731	Garage, Brookline.....	10,436	156,198	10,806	.085	1.23
729	Filter, Lawrence.....	19,993	149,250	19,208	.134	1.04
852	Fire station, Weston.....	6,757	44,265	2,982	.153	2.26
739	Observatory, Milton.....	3,625	9,734	657	.373	5.45
831	Filter, Warren	20,076	59,991	5,243	.333	3.82
	Highest.....				$.333	$3.82
	Lowest.....				.06	.90
	Average.....				.138	1.72

developed later that the concrete on the walls showed an actual loss instead of profit, and that the form work cost more than twice what was originally estimated that it should cost.

It was originally planned to tool the wall surfaces when the cement was less than ten days old, but on account of the various changes, forms had to be left on a considerably longer time and it was inconvenient to tool the surface until the cement was so thoroughly set that the cost of dressing was considerably greater than was first anticipated. Again, by reference to the 7/8 in. maple floor which was placed upon the concrete construction, a cost of $89.44 per M. bd. ft. will be observed, and by reference to the details on the back of the card it will be

seen that repairing floor cost $248.50, or $12.42 per thousand. This was due to the fact that the owners did not deliver or set the window sash at the time agreed and therefore the maple floors lay exposed to the weather in the building for several weeks, swelled and after laying shrunk, leaving large cracks which the owners insisted on being filled before they would accept the work. These experiences indicate how matters which appear trivial at the time may cause serious loss if overlooked.

As seen by the large list of items entering into the estimate as given by this master card, there are various items of cost

TABLE X.—COST OF FIREPROOF COMPLETE BUILDING.

Job No.	Location.	Job Cost.	Volume in cu. ft.	Floorarea in sq. ft.	Unit Cost. Per cu. ft.	Unit Cost. Per sq. ft.
	Storehouse, Nashua	$141,755	1,714,448	168,696	$.0827	$0.84
	Hospital, Buffalo	60,800	703,692	57,654	.0865	1.05
	Office Building, Everett	61,646	496,780	39,840	.124	1.545
	Cold storage, Boston	200,051	1,535,000	154,000	.13	1.30
	Factory, Chelsea	19,202	212,400	15,000	.091	1.28
	Factory, Cambridge	141,529	1,327,868	106,022	.107	1.335
	Storehouse, Saco					
	Manufacturing Building, Providence	76,796	1,140,000	146,000	.0685	.575
		91,377	1,380,500	90,240	.067	1.01
	Office, Jacksonville	136,880	693,840	56,552	.197	2.42
	Factory, Cambridge	133,064	105,600	8,800	.124	1.485
	Factory, Cambridge	75,604	1,211,364	74,604	.0625	1.01
	Factory, Cambridge	23,332	180,000	16,394	.129	1.42
	Highest				$.197	$2.42
	Lowest				.0625	.575
	Average				.1088	1.27

entering into the construction besides those which are enumerated. Nevertheless the matter of the forms, steel and concrete covers by far the largest proportion of the cost of a reinforced concrete structure and the minor items are those which are peculiar to each individual case and which any person can easily estimate for himself.

In addition to the unit costs given in Tables I-VIII, a few tables have been compiled of the total costs of buildings—that is the masonry and carpentry work without interior finish and decorating, plumbing or heating, which are more or less variable—trying to put the building on a comparative basis of the amount of work done on each. It has been a common method to estimate

the approximate cost of a building by either the square foot of floor space or the cubic foot of space enclosed. After making this comparison, the author is convinced that neither method is accurate enough to put much reliance on, the square foot method being a little safer than the other.

Table IX contains the total cost of actual contracts executed. Table X contains bona fide bids on complete buildings on which the author was not the lowest bidder but where the difference was not as a rule very great. Tables XI and XII cover bona fide bids on work by another contractor whose experience was similar

TABLE XI.—COST OF FIREPROOF BUILDINGS, Compiled by J. R. B.

Job No.	Location.	Cost.	Volume in cu. ft.	Floorarea in sq. ft.	Unit Cost.	
					per cu. ft.	per sq. ft.
	Office Building, Boston	$70,690	441,000	35,854	$0.159	$1.97
	Cold Storage, Boston	132,365	1,016,400	101,640	.13	1.30
	Hospital, Methuen	44,451	348,320	34,832	.127	1.27
	Hospital, Monson	51,574	414,732	29,838	.124	1.73
	Bank, Springfield	65,580	533,750	.....	.123	.....
	Masonic, Dayton	180,197	1,479,456	.....	.122	.....
	Warehouse, Provincetown	31,280	259,700	24,500	.120	1.28
	Garage, Boston	59,105	497,420	.....	.118	.....
	Warehouse, Boston	275,723	2,597,000	212,000	.106	1.30
	Hotel, Louisville	220,646	2,116,106	.....	.104	.....
	Hospital, Grafton	40,724	485,789	38,247	.100	1.30
	Office, Boston	25,151	264,687	.....	.095	.....
	Cold storage, Worcester	82,711	909,240	66,745	.091	1.24
	Club, Roxbury	43,586	513,808	.....	.085	.....
	Office, Boston	60,003	501,575	67,400	.084	1.12
	Highest				$0.159	$1.97
	Lowest				.084	1.12
	Average				.113	1.39
	Variation high and low, per cent				53.8	57.0

to that of the author. As a rule, cubic foot measurements are given in cents only, seldom being carried to any closer subdivision. In reference to Table XII on second-class buildings, it will be noted that for the largest building a variation of one cent per cu. ft. amounts to over $28,000, while the smallest one in the list amounts to only a little over $5,400. Again, on the last three items, the cu. ft. price is practically identical, while the square foot measurements corresponding vary by more than 100 per cent. with no apparent reason in the design.

In Table XI another discrepancy is noticed. In the first and the last items the highest and the lowest price per cu. ft. as

well as per sq. ft. are on office buildings of a similar type within one mile of each other where there is no apparent reason for such discrepancy in the design or difficulty of access in the erection of the building. It is recommended that very little reliance be placed upon this class of estimates.

So much has been said regarding the cost of moderate priced dwelling houses of reinforced concrete, an estimate has been made on four of the prize designs of the competition held by the Association of American Portland Cement Manufacturers. These have been figured out on average unit costs given in the

TABLE XII.—COST OF MILL CONSTRUCTION ON SECOND-CLASS BUILDINGS, Compiled by J. R. B.

Job No.	Location.	Cost.	Volume in cu. ft.	Floorarea in sq. ft.	Unit Cost.	
					Per cu. ft.	Per sq. ft.
	Mill, S. Boston	$66,516	544,788	44,172	$.122	$1.51
	Warehouse, Boston	337,000	2,808,850	.....	.12	.....
	Mill, S. Boston	113,288	1,271,300	129,920	.0891	.875
	Storehouse, Nashua	101,098	1,714,448	168,696	.059	.60
	Mill, Easthampton	90,703	1,622,128	152,200	.056	.60
	Mill, Fitchburg	72,048	1,331,200	83,300	.054	.865
	Mill, Woonsocket	85,754	1,752,609	81,500	.048	1.05
	Mill, Centreville	122,128	2,641,000	98,059	.046	1.25
	Mill, Pawtucket	94,341	2,036,731	174,000	.046	.542
	Mill, Fitchburg	129,405	2,867,535	157,730	.045	.82
	Highest				$.122	$1.51
	Lowest				.045	.542
	Average				.069	.90

accompanying tables. First prize was for a $2,000 house, single and double, and for a $4,500 house, single and double. The first figure is for a house as designed by the successful competitor, the second figure for a distinctly monolithic fireproof house on the same design. It will be seen that these houses cost more when estimated, based upon the experience hereinbefore given, than the sort given in the competition. It is nevertheless the author's opinion that small detached houses cannot be built as cheap as a rule as the average unit price upon which the estimate is based, because these unit prices are obtained from much larger buildings, the majority of which are much plainer in design, which thereby simplifies the construction.

There has been some inquiry regarding the cost of workmen's cottages, and a design has been made for a block house

to be built in not less than twenty at any one time in blocks of ten or more in length. These are two-story houses with cellar for storage of coal, two rooms on the first floor, four chambers and toilet on the second; 17 ft. front, 27 ft. deep, fireproof throughout. These could be built for $1,600 each, or 16.9 cents per cu. ft. and $1.73 per sq. ft. of floor space. If built of the same design only of wood, the cost is estimated to be $1,355, or

TABLE XIII.—COST OF FOUR HOUSES.—PRIZE DESIGNS FROM THE COMPETITION HELD BY THE ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS.

The houses are complete except for heating, lighting and plumbing. The third column is figured out from unit costs given in the preceding tables for a house with concrete walls and wooden interior as per the competition; the fourth column is for the same house built entirely fireproof.

Design.	Limit in the Competition.	Cost as per Competition.	Cost. All fireproof.
No. 158, Eugene Ward, Jr., Architect. Single house, 26′ front x 20′ 8″ deep; 2 stories and cellar; 4 rooms and bath	$2,000	$3,694	$4,315
No. 177, Andrew Lindsay, Architect. Double house, 66′ 6″ front x 28′ deep; 1½ stories and ½ cellar; 4 rooms and bath	4,000	6,716	8,385
No. 96, W. Cornell Appleton, Architect. Single house, 33′ front x 28′ deep; 2 stories and cellar; 7 rooms and bath	4,500	5,847	7,112
No. 156, Eugene Ward, Jr., Architect. Double house, 72′ 8″ front x 30′ 10″ deep; 2½ stories and cellar; 8 rooms and bath	9,000	10,440	12,507

14½ cents per cu. ft., $1.48 per sq. ft.,—a saving between concrete and wood of $245, or 15.3 per cent. Considering the severe wear and tear such a house receives from the class of people who occupy it, this difference in price is very well justified. Prices given here are for everything necessary for the building complete, ready for immediate occupancy.

DISCUSSION.

Mr. F. H. Beebe.—I would like to ask how the separation of materials is made between columns and floors and walls and foundations? **Mr. Beebe.**

Mr. Leonard C. Wason.—That is a very simple matter, because, as a rule, columns are filled in one day, walls another day, floors at a different time. Where, on account of rush of work or other circumstances, some of each kind of the work is done on the same day, the volume of concrete is measured in place. The empty cement bags at the mixer are counted, and are kept in separate piles for each kind of work by the foreman. He tells the man in charge there, when he is on columns, to keep them in separate piles, and the same applies to floors, walls and foundations. After measuring the concrete in floors, by working backwards we find the amount of stone and sand used, also the number of cubic feet of concrete per barrel of cement. **Mr. Wason.**

Mr. W. P. Anderson.—We have been in the habit of keeping our cost and arriving at our estimate in very much the same way as Mr. Wason. We keep the form work entirely separate from the concrete, and obtain a price for the form work on a job. This is determined by counting the superficial feet in contact with the concrete, taking the columns on all sides, the two sides of walls, beams and girders, and of the entire floor area. In getting these quantities we make no deductions for any intersections. If the building is 100 feet long, no matter how many cross-girders come in, we count the form work as 100 feet long. With columns we take the full height, and make no deductions for the concrete where it is already counted in the floor, and thus the intersections are sometimes counted four times. There may be a beam going one way, and another beam going another way, but we always find that there is more or less loss that will make up for any additional concrete or form work that may be counted in that way. In reference to openings, we very seldom make any deduction, because it is nearly as much trouble, especially in **Mr. Anderson.**

Mr. Anderson. form work, to frame around the opening. You have to put your forms up about the same as if it were filled in. In the costs given by Mr. Wason he did not distinctly state whether there was any addition for superintendence and timekeeping and waterboy and things of that kind on the job.

Now, when we make up our cost, we lump those things in one item, so much a month. You can figure your superintendence for a month; and you have to have a timekeeper and a watchman and a waterboy, and, if the job is out of the city in which you are located, you will have to have some travelling expenses connected with it; and we arrive at those items by a monthly charge. There is also an engineer. He may be hoisting one class of material part of the time, and another class of material another time, and it is very hard to subdivide his time. So we make a separate item of that, and add that in at the end, in addition to all costs that came before. After that, the basis of our costs is somewhat different from that of Mr. Wason. We are a little bit cheaper in the placing of the concrete. I think that is probably due to the fact that he has included the installation of his machinery in the cost; we make a separate item of that. We allow so much on each job because, if it is a little job, the installation of your plant costs more in proportion to your concrete and material in the job than if the building is a large one.

I have no figures with me, but have them pretty well in my head, using them almost every day in making estimates, and I can give you a little idea of the varying costs under certain circumstances.

Now, we put up a 16-story office building in Cincinnati about five years ago, entirely of concrete. The cost per square foot of the form work in that building, counting it as I have described, was between 10 and 11 cts. per sq. ft. This includes the cost of the lumber, nails and labor, taking down the forms, and allowing a salvage for the lumber we could use over again. In other words, it was the total cost per square foot of the form work exposed to the concrete. If I remember rightly, the cost of placing the concrete was about $1.50 per cu. yd., including all the cost of labor at the building. Of course, the cost of material is the thing that varies in different sections, and we

always figure it separately. In determining the amount of material in a yard of concrete for reinforced work, we customarily use a 1-2-4 mix. The amount of sand and stone does not vary materially with the mix. It is so slight that there is not much use in making any difference, but the amount of cement does. Now, for the 1-2-4 mix, we figure a barrel and a half of cement to the cubic yard, half a yard of sand and a yard of stone or gravel. Theoretically, there will not be that much required, but I suppose a good many of you will notice that when you buy material you do not always get what you pay for. It shakes down in the cars, and there may also be a sagging of the forms, so we try to be on the safe side. It is impossible to make the forms so strong that they do not sag a little. If you use unscreened gravel, it does not take quite as much, because the gravel is not so filled with voids as is the crushed stone. It has sand in it, which the stone has not. It would apply, however, to a screened gravel, where the sand had been taken out. **Mr. Anderson.**

The cost of steel varies just about the way that Mr. Wason has given. It varies so much with the amount of bending, etc., that no really very accurate figures are possible. The cost of the form work in different kinds of buildings varies. We make no distinction between the walls or columns, or the beams or anything else, because we find when we are erecting a column that it is pretty hard to determine whether the carpenter when he gets to the top is putting the column up or the floor on. He may be putting the joists up to hold the column in place, and we have not been able to get any satisfactory division. I find it more accurate to give the same price to all things, no matter what it is, and vary the unit price according to the character of the building.

We put up a building about 100 ft. wide and 300 ft. long, with a 28 ft. story height, and a 40 ft. span. Above that, columns were run up for another story, no floor being put on, but a steel roof was placed on top of the column. It is expected to eventually take down the steel roof and use it again higher up when the additional story is added. It was a rush job, with a bonus and time limit. We had to work on Sundays and at night, and the cost in that case was about 16 cts. per sq. ft. of the surface

Mr. Anderson. in place, as described above. Of course, the walls probably did not cost that much, but the interior would cost more. The fact that it was a rush job and that the forms could not be used over again on this job increased the cost slightly. Of course, we could probably use the forms over again for columns, or things of that kind, but we could not get much duplication. Another reason for the high cost was the height; the props had to be so much longer. An ordinary story is 12 feet high, and it is not necessary to brace it so well as a 28 ft. story. Then, of course, the span being 40 ft. it required a little more expensive shoring than with a shorter span. One of the factors increasing the cost was the fact that the building was constructed with the form work on the ground. Above the first or second stories the form work is somewhat cheaper than on the ground, because on the ground every piece has to be levelled up to a different height. There is a tendency for it to settle, and you have to have a man around to see that no place settles more than another.

Those are some of the reasons that contributed to the high cost in that case. Also, when a person is starting in to do concrete work, the carpenters are not familiar with it—they are working in a manner reverse to what they have been accustomed. It is a little awkward to them at the start, and you will find it costs more than you think. If we were to erect the Ingalls Building again, we could probably save a cent or a cent and a half on the form work, and that building was only 5,000 sq. ft. to the floor. Now, in a large buildings, with, say 20,000 sq. ft. for each floor, with four or five typical stories, where the forms can be used over three or four times without change, and after the carpenters have become experienced, the form work will cost between 7 and 8 cts. per sq. ft. if the work is done under the best conditions. However, if the job has to be pushed, it costs more, because it requires more lumber. The lumber cannot be used over so often on account of the time required for the cement to set. Of course, there comes a point where your dead expense, if you dragged on too long, will eat up any saving by utilizing the same forms over a number of times. I would advise those without experience to add 2 or 3 cts. per sq. ft. to the prices given.

When we get our costs on a basis of that kind, we add something for equipment, and, of course, that depends on the size of the job. Generally, on an ordinary job, $600 to $1,000. We figure about $450 to $550 a month for expenses if we are taking the job outside of the city, in addition to the machinery cost. That will cover travelling expenses and watchman, superintendent, waterboy, and things of that nature. Of course, that would be on a big job, because we do not take any small jobs very far from home. We cannot afford to do it on account of having so much incidental expense, and the local man can generally do better. After the cost is derived we have to add about 7 per cent. to cover our fixed charges. Those fixed charges would be our office expense, liability insurance on the job, engineering and things of that nature, which are not included in the cost that I have mentioned. These figures do not include any profit which must be added, with an allowance for contingencies. I have found, and I think others who are in the reinforced concrete business also, that the fixed charge attached to this form of work is much higher than in any other form of contracting. You may get down to 2 or 3 per cent. on some, maybe lower than that, but on the reinforced concrete work it is bound to run up. The engineering and the trouble that you have in ordering, getting and keeping track of small pieces of steel, etc., is an item that you get fooled on when you first start in. **Mr. Anderson.**

I would like to ask Mr. Wason whether he has included superintendence and things of that kind in his costs.

MR. WASON.—The cost of superintendence, timekeeping and waterboy is all included in the item of general labor, which covers in addition everything which is not actually concrete labor. It includes the cost of cleaning up floors, receiving materials and so forth. **Mr. Wason.**

MR. H. C. TURNER.—I do not believe I can add very much to what has been said by Mr. Wason and Mr. Anderson. We are all anxious to arrive at an easy way of finding out the cost of work as suggested, but there is no such way. The great value of cost keeping is to broaden our knowledge of costs and correct our judgment in estimating future work, and for the purpose of determining exact costs as the work progresses. Often **Mr. Turner**

Mr. Turner. we will find opportunities to slightly modify methods which have been adopted and thereby reduce materially the unit costs as the work progresses. In order to do this, we must have the knowledge of the actual unit costs from week to week. There are a number of methods which can be devised for this purpose. Our system consists in first estimating the work, our method being similar to the one described by Mr. Anderson, and after obtaining the contract, to analyze the estimate, separating the labor from the materials and dividing it into the different operations which have to be carried through to build the structure. We give each operation a number. For illustration, No. 1 represents the labor, skilled and unskilled, in making the form work. No. 2 represents all labor on form work in connection with footings, and No. 3 represents all labor expended in setting up and taking down the floor and column forms. Our blanks for reporting the time to the office contain these various classifications. The timekeeper divides the labor each day among the different operations or classifications, 1, 2, 3, 4, etc., and mails them daily to the main office. With this information, the pay-roll clerk makes up the weekly pay-rolls and the summary cost sheets, which must check as to totals. The cost-keeping department estimates the quantity of work actually done during the week and with the summary labor cost sheets carries out the exact unit costs. This report is given to the President and to the General Superintendent. The General Superintendent discusses the unit costs with the Superintendents and if the costs are excessive, a strenuous effort is made to reduce them. It should be noted also that the moral effect on the entire force is excellent. There is a great deal to be gained in this respect, as it has a marked influence upon every workman on the job if he knows that the boss knows what the work is costing.

The important point in determining how the costs shall be divided is to select operations which are repeated. For instance, we have No. 3, which is setting up and taking down floor forms. Now, No. 3 will occur on the first floor, on the second floor, on the third floor, and so on. So we subdivide this work as 3_1 which will include all labor in erecting and removing the forms for the first floor; 3_2 will include the same labor for the second

floor, 3_3 for the third floor, and so on to the top of the building. When you have plotted these unit costs graphically, you should have a straight line, if the work was started right and the efficiency maintained. We, however, always find the unit cost a little higher on the lower floors, reducing as we go up, for the reason that the workmen become better acquainted with what is expected of them. **Mr. Turner.**

We have noticed particularly that the important thing in obtaining efficiency is for the superintendent to know exactly what he wants his workmen to do, and for the foreman over the workmen to be able to direct and require every individual to do his work without lost motion, without lost effort. We all realize ourselves that we can probably do five or ten or fifteen per cent. more work if we try, and the great thing is to show the workmen how they can increase the efficiency of their labor. That can only be done by knowing in detail just how the work must be conducted.

Now, as to being able to estimate costs per cubic yard of concrete from one job to another, we have found this to be impossible. The form work is the largest single item, and the form work varies with each different building, depending upon story heights, depth of beams, spacing of columns, and also, of course, upon the conditions surrounding the locality, the room in which to work, and the ease with which the materials can be delivered.

We divide our estimates into form work, steel work and concrete work and into all other items which are distinct. After making up our total cost of labor and materials, we have our top charges, as have been explained by Mr. Anderson; an allowance for installation of plant; another for superintendence; another for engineering and construction drawings; and then a contingency charge to cover unforeseen conditions which arise on all work.

It is possible to make comparisons of the cost of buildings per cubic foot of contents, but in making such comparisons it is necessary to take into consideration story heights, the length of spans, the loads, and many other items. This cubic foot price in our experience has varied from 6½ cts. to 12 cts. per cu. ft., depending upon these conditions. We invariably check our esti-

Mr. Turner. mates before presenting them by the cubic foot check, and any very large error would be detected.

Now, I do not believe it will ever be possible, by means of any cost-keeping system, to sit in the office and determine the cost of work. Judgment cannot be eliminated in this respect. It is always necessary to visit locations and study them in detail, as they are variable, and are matters bearing upon costs. The purpose of the cost-keeping system is to improve the judgment of the estimating engineers, and to aid the superintendent in obtaining efficiency.

Mr. Lindau. MR. A. E. LINDAU.—What has struck me most forcibly in this connection is that in addition to the figures Mr. Wason has given us, it is necessary to have more information as to the price of materials and cost of labor in each particular case in order to properly compare costs, based on units of square foot or cubic foot, of similar structures in different localities. In addition to this the matter of union labor must be reckoned with. In St. Louis all reinforced concrete work is controlled by the unions. The framing is all done by members of the Carpenters' Union; the material in wheelbarrows is handled by members of the Cementers' Union; and the steel is placed by structural iron workers. In addition to the high scale of wages asked by members of unions, the cost of construction is frequently increased by the squabbles among the various unions as to the division of labor. As a case in point, I have in mind a terra cotta cornice overhanging a building four or five feet, the back of which was to be filled with cinder concrete. The bricklayers claimed this as part of their work, and as they do all of their work with a trowel, insisted on placing all of this cinder concrete that way. As a consequence the job was tied up for a week or ten days until the matter was adjusted.

In another case in which our company was interested as a contractor, trouble arose between the carpenters and the structural steel men as to who should put on the wire hangers supporting the soffit boards under the I beams, the carpenters claiming everything touching wood, and the steel men everything touching steel. The matter was finally settled by paying a walking delegate for one of the unions so many dollars per day as seemed necessary to satisfy that organization.

Another point of interest would be some information in a general way as to the relative costs of various types of floor construction, from which could be obtained the economical limit, say, of slab-construction as against a panel sub-divided by beams; also the bearing on floor cost extension beams and columns as against wall-bearing floors. These facts can be obtained by the careful contractors and would serve as a general guide in design. Mr. Lindau.

MR. H. B. ANDREWS.—There is one point on which none of the preceding speakers have touched—the cost of doing concrete work in cold weather. It seems that while it is generally contemplated that the work should be finished before cold weather sets in, it is hardly ever the case. We are always running into cold weather. For example, in finishing buildings with granolithic floors it is generally impractical to put the floors on at the time the base is put in, for if you do so in cold weather, they are liable to freeze and scale, and the owners are not satisfied with the floors. Therefore, some provision has to be made for putting on the floor finish afterward. This costs more money. Now, I wish Mr. Wason or some of the other speakers would tell us what extra cost there is for doing the work in cold weather. Mr. Andrews.

MR. WASON.—I have one job in mind where 35,000 sq. ft. were placed in the open air, in midwinter, when the thermometer never rose above 25 degrees F., and seldom rose above 15. The total cost of the job was a little over $20,000. The extra cost, on account of the cold weather, was about $1,000, or 5 per cent. The work came out perfect. Those floors were put in with a rough surface. After the spring came and the roof had been built over this floor, the finish was put on. This cost probably 5 cts. per sq. ft. more than if it had been put on in warm weather at one operation as an integral part of the floor construction. Mr. Wason.

I have another job in mind where the contract price was about $36,000, where the work thawed and froze. Some of the concrete had to be taken out and done over. The method of procedure, as a protection against cold weather, was to heat the sand with live steam to take the frost all out of it, and then allowing it to be mixed with the stone quite a little while in

Mr. Wason. the mixer it took the frost off the stone; also salt water was used. The forms were sprinkled with salt, and the top surface of the concrete was also sprinkled until it looked like a frost. This produced a strong brine on each surface and prevented freezing. The second job also cost about 5 per cent. over warm weather prices.

Mr. Porter. MR. H. F. PORTER.—I think Mr. Turner hit the nail on the head when he said that this cost-keeping was so largely a matter of judgment, and, therefore, it is with a great deal of danger, I think, that the subject is brought up, and this industry is still very young, and it is already strewn with a great many wrecks, due to people trying to do work on other people's figures which they knew nothing about; and, therefore, while Mr. Wason's figures may be of great value to him, I seriously doubt if they will be of very much value to anybody else who would not know the conditions under which those figures were arrived at.

Now, I think, of the conditions which would make the figures valuable to him and not to us, there would be, first, the locality. They are probably arrived at mostly around Boston, and the labor conditions of Boston and Cincinnati and New York and Philadelphia and Canada are entirely different propositions. Last winter I had a job in Toronto, and the labor conditions up there were considerably different than I found them in Philadelphia, and again different than I found them in Chicago, and all those things affect the cost.

Then there is the vital factor of organization. One may easily reduce the cost of putting in concrete by an ingenious plan and by a skillful supervision and by using good judgment, so as to preserve and produce harmony in the details of the operation and to cut down the time to a minimum. It may easily reduce the cost one-half. I know on one job after the second floor we succeeded in reducing the expense of placing the concrete from $1.50 to 75 cents by a smoothing out of the organization. So that when the personal equation is so large it is pretty dangerous, and I don't want to advise any friend of mine to take my figures and try to do any work from them. It is something he has to dig in and learn gradually, until finally he gets to the point where he knows enough to bid, from his own experience.

MR. WM. M. BAILEY.—I know myself that oftentimes the cost of work has been reduced at least 50 per cent. by smoothing out the organization, as Mr. Porter says. In one particular case concrete on one floor cost about $1.50 per cu. yd. for labor, and the cost on the second floor was reduced to 90 cts. Oftentimes the foreman himself can reduce these costs. One man can make the work cost at least 15 per cent. for labor more than another. **Mr. Bailey.**

MR. J. R. GLOYD.—In trying to reduce the cost of labor on a job, it has been our experience that by the general superintendent visiting the job every two or three days, or during the day the concrete is under way, and going over the work with the foreman or the superintendent in charge, he will find many points that the superintendent or foreman in charge did not see, which will materially reduce the cost of handling the material and labor in connection with the work. **Mr. Gloyd.**

And another point I would like to make is, I am a firm believer in instilling a spirit of rivalry in a way between the superintendents on the various jobs, and in that way we give the superintendents the actual labor cost anywhere on their jobs, on the other jobs in progress at the same time, or similar jobs they have done. We do not give them any idea of the cost of materials, but simply the labor and the different items, which instils a very healthy rivalry and helps to reduce the cost of labor to the lowest point.

MR. WASON.—Mr. Porter expresses disapproval of the principle of publishing cost data on the ground that it would mislead others. Anyone who uses it will have experience to realize that the costs cannot be exactly duplicated even by the same man. Nevertheless, this data is useful to those who have had no experience at all. The averages in tables ought to be a fair comparison with the average conditions found elsewhere, and an inexperienced person would be very foolish to use a lower price. **Mr. Wason.**

It has been the experience of the author that novices have very much underrated the actual cost of construction much to their own hurt. It is for the benefit of such that this article was prepared, and if a person keeps in mind how this data was obtained, and all the statements made in connection with it, he can safely use the figures given.

COMPARATIVE COST OF REINFORCED CONCRETE BUILDINGS.

By Emile G. Perrot, Assoc. M. Am. Soc. C. E.*

The use of plain concrete for footings, foundations and as a substitute for massive masonry wall construction, has come to be generally accepted by the building world of to-day. Even the most skeptical as to its use for columns and beams, do not hesitate to use concrete in the above manner. As the constitutional infirmities of plain concrete became more evident and its use consequently restricted, means for overcoming these weaknesses by reinforcing the material with iron or steel rods at once opened up the field of application of concrete, so that to-day entire structures from footing to top of cornice or parapet are constructed solely of this material.

Apart from the mere adaptability of a material for building purposes, owners when investing large sums of money in real estate, must take into consideration the economical aspect of the construction. Aside from the desire to conserve their property (that is, to build so as not to burn), the saving on the insurance premium is very often a controlling factor in the selection of a type of construction to use. Twenty-five years ago the idea of making buildings of the factory type fireproof was uncommon; almost any sort of structure was deemed fit to use for manufacturing purposes. As the ascendency of the United States in the manufacturing world became great and we commenced to lead in the manufacture of the world's products, architects and engineers at once saw a field for their labors that had heretofore been left to the caprice of untrained minds, it being the exception for an architect or engineer to be consulted in the designing of a strictly factory building. To-day, however, thanks to the insistence of the insurance companies on higher standards, the design of almost all manufacturing buildings is attended with much study and they are usually built under the supervision of a competent archi-

* Ballinger and Perrot, Architects, Philadelphia, Pa.

tect or engineer. This change in methods has led to a much higher standard of building, and with the advent of reinforced concrete has come the commencement of a period when fireproof factory buildings are to be the rule instead of the exception.

We all know how the so-called "slow burning" type of mill construction supplanted the joist constructed building a few years back: how the building laws of large cities classify the buildings into first, second, third class, etc., according to their degree of fireproofness; how insurance companies are lowering the premium on fireproof buildings; in fact, the tendency to-day is towards a better grade of building. And it is right that it should be so, since what a farce would be our boasted twentieth century civilization should we still be content with the undesirable firetraps erected by our forefathers.

We hear to-day a great deal concerning the scarcity of lumber; perhaps it is a good thing that lumber is becoming more expensive and the price almost prohibitive, for then we turn our thoughts to a substitute, and in doing so improve upon the methods that have been in vogue. The optimist's reply to the lumber question is, use reinforced concrete or concrete lumber, build so as not to burn, make your work permanent; reduce the cost of maintenance on your building, get lower insurance rates, or better still, eliminate insurance. What is the need of insurance when the amount of inflammable material is reduced to a minimum? The cost of a building is very little more, and the interest on the additional investment is usually less than the insurance premium.

That the science of reinforced concrete has arrived at that state where we can with a certainty declare its adaptability for fireproof building construction, is a question beyond a doubt, as instanced by the many hundred reinforced concrete buildings erected and in use in this country, as well as by the result of actual fires that have taken place in such buildings. The writer has had to do with one such building where a fire completely destroyed the japanning kilns in the upper floor of a building without in any way affecting the concrete construction.

As to the increased cost of reinforced concrete over slow burning mill construction, everything else being equal, it varies

from ten to thirty per cent., according to the heaviness of the construction and the size of the building, also the number of times the forms can be reused.

Some buildings have been erected in which the floor loads were such as to preclude the use of heavy yellow pine timbers, as the sizes required would have been larger than it is practicable to obtain. On the other hand, the use of steel beam girders fireproofed would have added to the cost sufficiently to make the composite construction equal the cost of a pure reinforced concrete building. I have designed structures of this class and they were erected at a very low cost, in fact, as cheaply as some buildings of slow burning mill construction.

In addition to the saving on insurance by having a fireproof reinforced concrete building, there must be taken into consideration the effect of wear and tear on the building if of the ordinary type; this is especially true where vibrating machinery is used. This is the case in a certain leather factory, where the glazing machines are situated on the third floor. These machines were formerly in an upper story of a brick and joist constructed building, and produced so much vibration as to cause alarm to the owners, as well as making necessary constant attention to the shafting and machinery in the way of adjustment, and consequently adding considerably to the running expense. In their new location, the vibration is absent and the cost of up-keep on machinery and shafting is reduced so much as to amount to very little compared to the cost in the former building. These considerations are hard to figure in dollars and cents to determine just what the saving would be for every case, but it is one of those small leaks in business which make for a large profit-producing business as compared with one where profits are scant.

In comparing the cost of reinforced concrete construction with steel construction fireproofed, we find that concrete construction is cheaper than the steel construction fireproofed. Actual bids on the two types of construction for the same buildings obtained reveal some interesting facts.

For the Ketterlinus building in Philadelphia, which is an eight-story and basement building, reinforced concrete was decidedly cheaper by about twenty per cent. and made a much stiffer

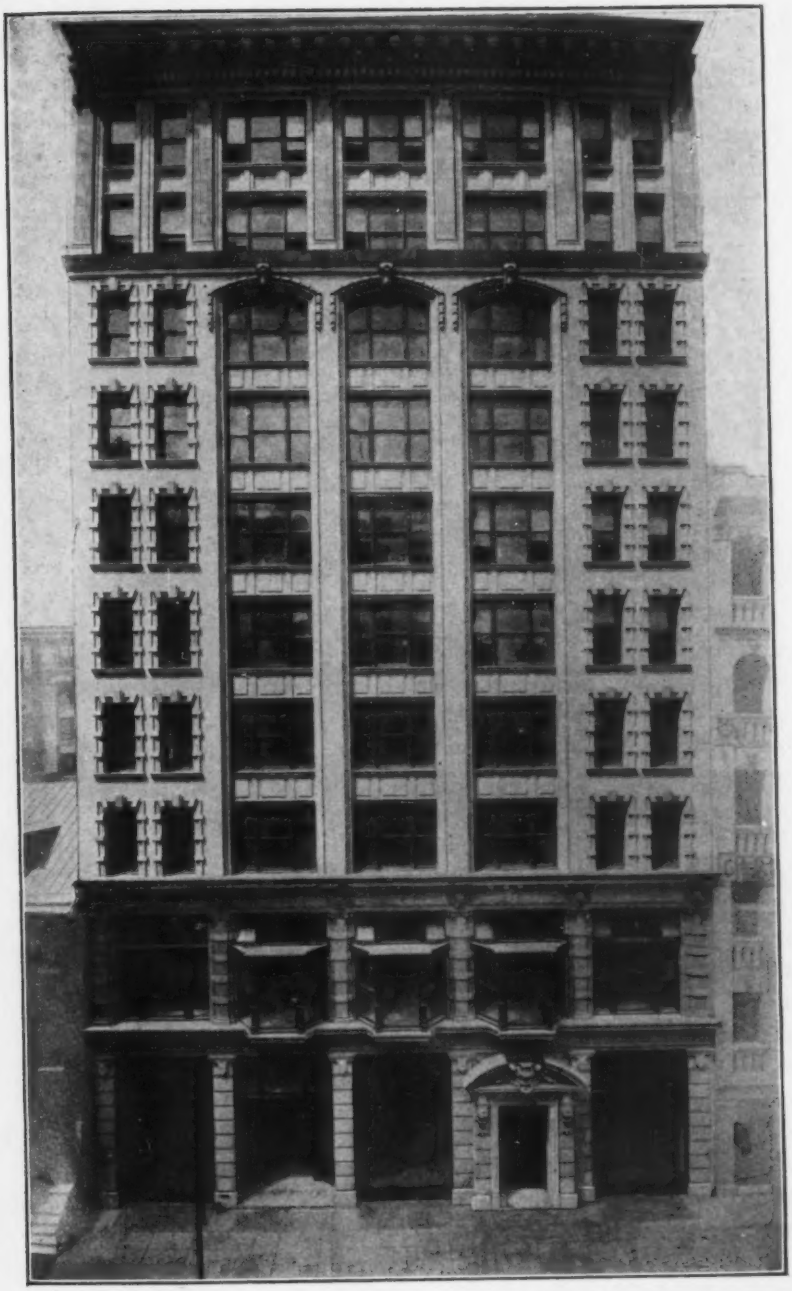

FIG. 1.—BOYERTOWN BUILDING. CONCRETE CAGE. HIGHEST REINFORCED CONCRETE BUILDING IN PHILADELPHIA.

building to resist the shocks of the heavy lithographic presses in the fifth and sixth stories of the building. This building has heavy concrete wall piers on the street fronts veneered with 4 inches of mottled brick secured with copper ties. There are heavy reinforced concrete brackets connecting columns with girders and beams, and the floor system consists of deep girders and beams spaced about 4 feet 6 inches center to center for beams, the slab being 4 inches thick. The column footings are reinforced concrete but the interior columns for five stories are of structural steel fireproofed.

Another notable instance of the saving effected by the use of reinforced concrete is the Boyertown Building, Philadelphia. The owners saved about $60,000 by the skilful use of reinforced concrete for the entire construction, representing a saving of about thirty per cent. Fig. 1 shows the character of this building; it is ten stories and basement, built of a concrete cage having the front veneered with granite in the first story and brick and terra cotta in the upper stories. The side walls are adjacent to party lines having simple reinforced concrete columns spaced about every 8 feet 6 inch centers to carry the floors and roof. Those in the basement were set back from the party lines sufficiently far to build a continuous reinforced concrete footing within the property lines of the building, thus compelling the use of heavy reinforced concrete cantilever girders at the first floor level to carry the wall columns above; the load on the end of the cantilevers is 385,000 pounds, and the leverage 29 inches. The rear wall of the building is carried on cantilevers at each floor, due to a recess in the first story of the building for a shipping department. These cantilevers are seven feet long, but while they are much longer than those carrying the side walls, they carry less load since there are cantilevers at each floor on the rear, while on the sides they exist only at the first floor level and carry nine floors and a roof. These are the heaviest concrete cantilevers ever built in Philadelphia, as far as I know. The reinforcement used throughout is cold twisted steel rods, except the columns in the interior and some of the front wall columns where structural steel cores are used.

Figs. 2 and 3 illustrate buildings of a reinforced concrete cage with brick veneer. Fig. 4 shows the application of concrete to a garage with the use of colored tile.

A very marked saving was effected by the use of concrete over brick for the wall construction of the buildings of the Jeanesville Iron Works, erected at Hazleton, Pa. This plant con-

FIG. 2.—STORE OF SMITH, KLINE AND FRENCH COMPANY, PHILADELPHIA, PA. CONCRETE CAGE. BRICK VENEER.

sists of a machine shop, foundry, pattern and pattern storage buildings, power house and office buildings. All walls of these

buildings are concrete and are monolithic. Concrete was decided upon for use in the walls because it effected a considerable saving over brick walls. As the site of the plant was such as to require

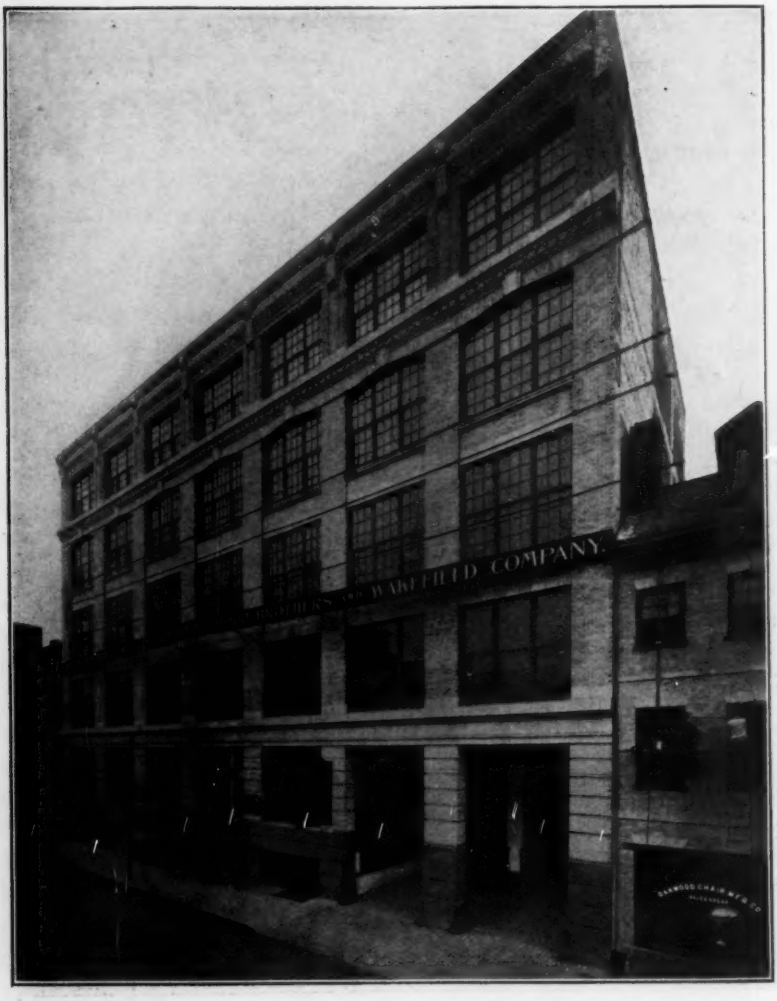

FIG. 3.—WAREHOUSE, PHILADELPHIA, PA. CONCRETE CAGE. BRICK VENEER.

considerable grading, and there were large quantities of rocks or mountain stones on the premises, the problem of bringing the ground to grade was most economically met by making the walls

of the buildings of concrete. By this arrangement, the contractor performed the grading without additional cost to the owner, using the stones in the concrete walls, making their removal unnecessary, and at the same time saving the cost of transportation of other materials for the walls.

FIG. 4.—SOLID REINFORCED CONCRETE GARAGE, ENRICHED WITH COLORED TILE. PHILADELPHIA, PA.

Where sanitary precautions and immunity from deterioration are the controlling factors, reinforced concrete offers one of the best forms of construction; this is exemplified in the new

plant of the Crane Ice Cream Company of Philadelphia, in which reinforced concrete was decided upon after an extended test to determine the action of salt water used in their business on the concrete and steel. The preliminary test and the actual use of the building for the past three years has demonstrated the fitness of reinforced concrete for this type of building. The plant is considered ideal, and its cost of construction was below the average for reinforced concrete construction.

To sum up, the cost of reinforced concrete buildings can best be considered by classifying them under several headings:

1st. Warehouses and manufactories. Cost, 8 to 11 cents per cubic foot.

2d. Stores and loft buildings. Cost, 11 to 17 cents per cubic foot.

3d. Miscellaneous, such as schools and hospitals. Cost, 15 to 20 cents per cubic foot.

These costs include the building complete, omitting power, heat, light, elevators and decorations or furnishings. The above prices are taken from the costs of buildings actually erected.

While it is customary to give the price per cubic foot, in comparing the cost of buildings, I myself do not consider that this basis of calculation always gives an accurate cost of a building, when the number of square feet of floor space is the governing feature.

For instance, in one building erected from our plans the cost per cubic foot was $0.104 or $1.30 per square foot, while in another building, of a higher grade, the cost was only $0.092 per cubic foot, as compared with $0.104 in the former case and $1.36 per square foot as compared with $1.30; the square foot price of the latter being higher and the cubic foot price lower than in the former case.

MONOLITHIC CONCRETE WALL BUILDINGS—METHODS, CONSTRUCTION AND COST.

By Robert Aiken.*

Man's first step towards civilization was in the erection of a shelter in which to live.

Wood, stone and brick are the building materials which have served as stepping stones and marked the stages of his advancement from the cave and the skin tent to the temple and the palace. Steel, hollow tile and terra cotta, adjuncts of strength, economy and beauty, are of comparatively modern use.

Now we are upon the threshold of a new era of construction, to which the artist, the architect and the mechanic must readapt themselves—an era that has just dawned and is appropriately christened "The Age of Concrete."

The story of its advent is most patently told in the simple statistics of cement consumption, which in 1895 was less than a million barrels for the whole United States, but which increased to over *forty millions* (1908), or about half a barrel for every man, woman and child in the entire United States.

Yet with this rapid growth in the production of cement, outrivalling in quantity that of any other material for an equal period, our knowledge of the practical uses of concrete is to-day about on a par with our knowledge of the application of the power of electricity thirty years ago.

Anything, therefore, which promotes, or even bears upon, the more efficient, economical or artistic use of concrete in the erection of structures is, or ought to be, of vital interest to civilization.

For all of these reasons, with all of which it aptly complies, the recent invention of a new mechanical method of erecting buildings of concrete without the use of forms or false work, doing entirely away with the costly, cumbersome practice of erecting two walls of wood in order to get one wall of con-

*Chicago, Ill.

crete, is by itself alone an invention of great moment and world-wide value, especially in these days of scarce lumber and high-priced labor. But added to this are several other improvements, less startling, but no less useful and valuable, which intertwine with and make more practical, efficient, economical, strong, artistic and perfect the main idea of the construction of monolithic concrete walls.

Of this perhaps the most lucid description would be to give the history of the invention followed by a description of its practical application to the construction of buildings.

The first use of this idea in wall construction was in the erection some years ago of a simple straight wall of reinforced concrete five inches thick, for a retaining wall. It was constructed flat upon the ground like a sidewalk and raised on one edge, and it was tipped into position by a derrick on a prepared foundation, where it was anchored by steel rods to buried blocks of concrete and became, so far as we know, the first concrete wall erected without forms.

Since then I have improvised and constructed more than half a mile of such retaining walls for target abutments at the Camp Logan (Illinois) Rifle Range and as many more for several other States.

While this wall was lying upon the ground in process of construction the thought occurred to me, while walking over it one day, that it would be possible to build the wall of a building in this way, leaving the proper openings for doors and windows, and tip it into place as the side of a house; connecting the corners by twisting together the projecting reinforcing rods and with an upright mold encase them in concrete.

This has since been improved by casting a pier on one wall with an overhung corner, with which the other wall engages when both are in upright position, thus avoiding a discernible joint on the outside. An 8-inch board is then braced upright against the joint on the inside and wet concrete poured in at the top to close the gap over the intertwisted reinforcing rods. This 8-inch board is the only false work used in the construction of the entire wall.

After finishing an abutment it was so satisfactory that the State of Illinois ordered four barrack buildings, 60 x 80 ft., and a

two-story building. Subsequently I built for myself of this construction a factory building with a saw-tooth roof, 75 x 80 ft., on my farm adjoining Zion City, Ill., for the manufacture of the targets and steel target frames.

The walls of this factory, the first complete building of this type of construction, were 14 ft. high. They were cast flat upon the ground on a smooth bed of sand prepared for them, then tipped into place as previously described. But in this case the door frames and window casings were first set in place and the concrete wall poured around them, the outer edges of the entire wall being formed by 6-inch boards like a concrete sidewalk; the

FIG. 1.—AMMUNITION AND GUN HOUSE, CAMP LOGAN, ILL.

wall was then tipped upon the foundation by block and pulley derricks and horse power. This crude method, however, produced only a single solid wall, which, while considerably waterproofed by the trowel finish on its outer surface, was lacking in air space and proper qualities for inside plastering.

The next building was a two-story ammunition and gun house for Camp Logan (Fig. 1), requiring floors of concrete and air spaced walls. The outer walls for this structure were made as above, except that they had the added improvement of window and door caps, sills and water table and panel joints troweled upon their outer surfaces while still lying flat.

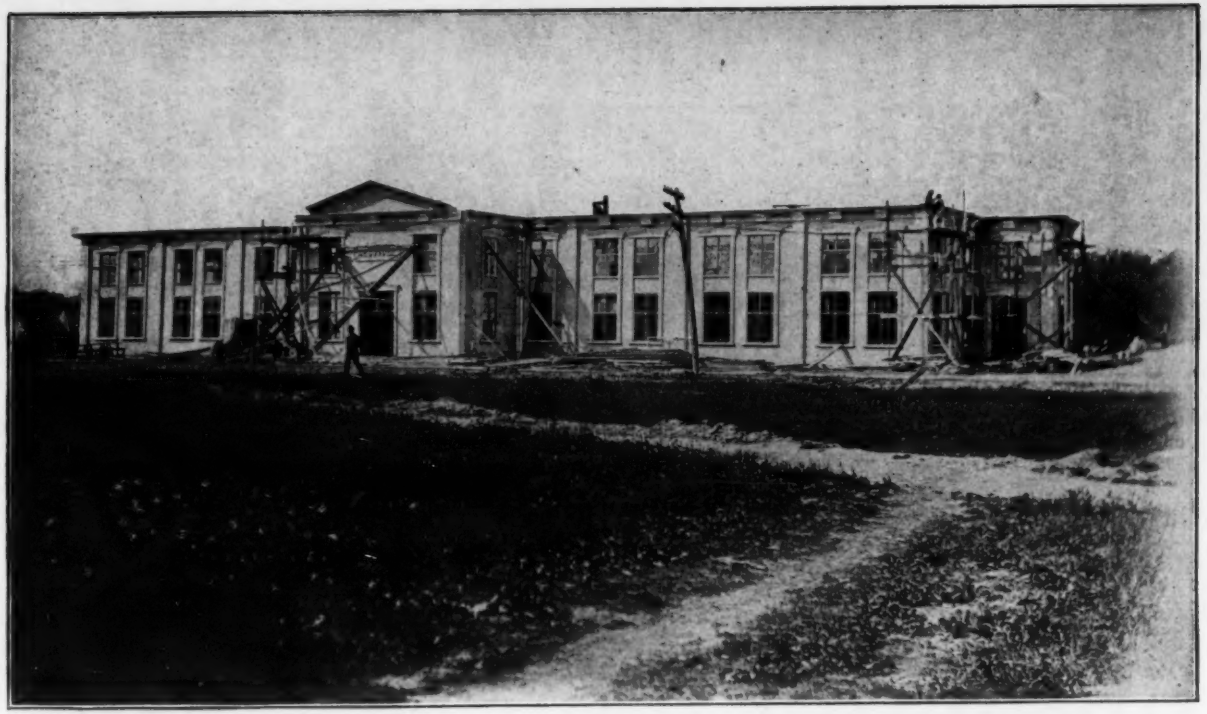

FIG. 2.—CONCRETE MESS HALL BUILDING, 192 X 132 FEET, AT CAMP PERRY, OHIO. BUILT IN 28 DAYS.

The air space was secured by an inner wall made of thin panels or slabs of concrete fastened into place and plastered. It was at this time that it was suggested that on the sand bed

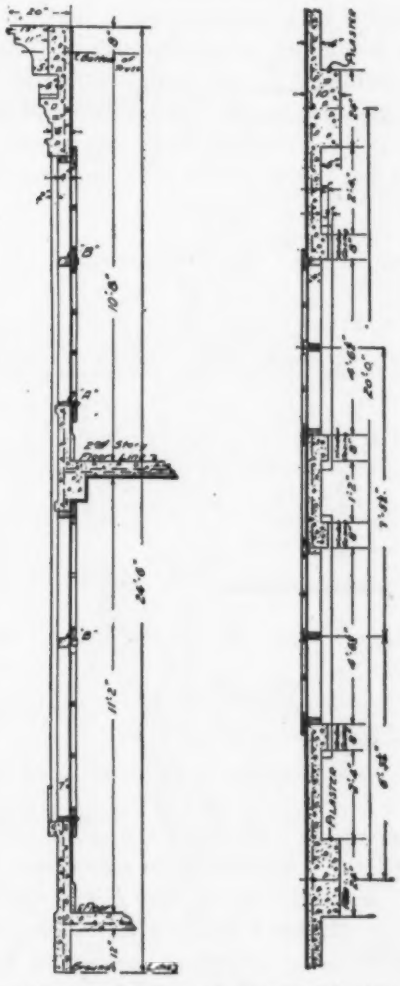

FIG. 3.—DETAIL OF WALL SECTION.

prepared for casting the wall should be laid strips of wood sunk into the surface of the sand bed and studded with projecting nails, which nails would be imbedded in the concrete of the wall laid

upon them, so that when it was raised it would carry with it the wooden uprights projecting from its inner face, upon which could then be tacked laths, which, when plastered, would leave an air space between the plaster and the concrete.

This suggestion was improved upon and led to the method for producing a double air space concrete wall finished or ornamented on both surfaces in one complete operation. Moreover, this wall is cast upon a tipping table under full mechanical control of specially designed lifting jacks, by which two men in an hour have lifted the finished side of a building, 76 ft. long, 27

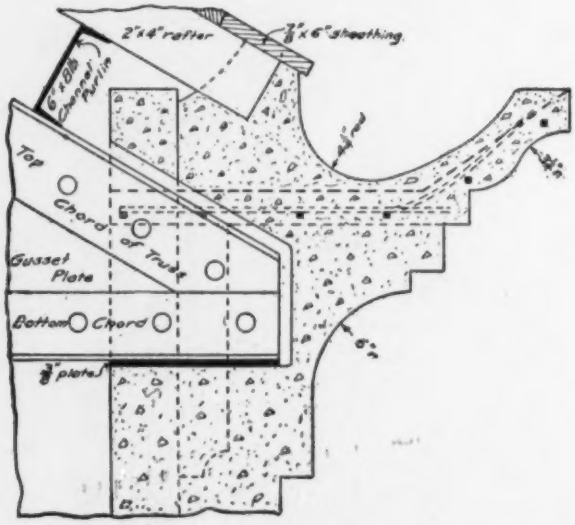

FIG. 4.—DETAILS OF CONCRETE CORNICE AT CAMP PERRY, OHIO.

ft. high and weighing 76 tons, from the prone position in which it was poured and set it accurately in place upon its permanent foundations, and, in another case, have lifted and set in position a wall 140 ft. long without a crack.

More than a mile of abutment walls and fifteen separate structures of one kind and another, in five different States, and, up to this time, of one and two stories only, have been reared of this construction.

There is no reason why structures of a dozen or more stories in height could not be reared, as it is readily apparent

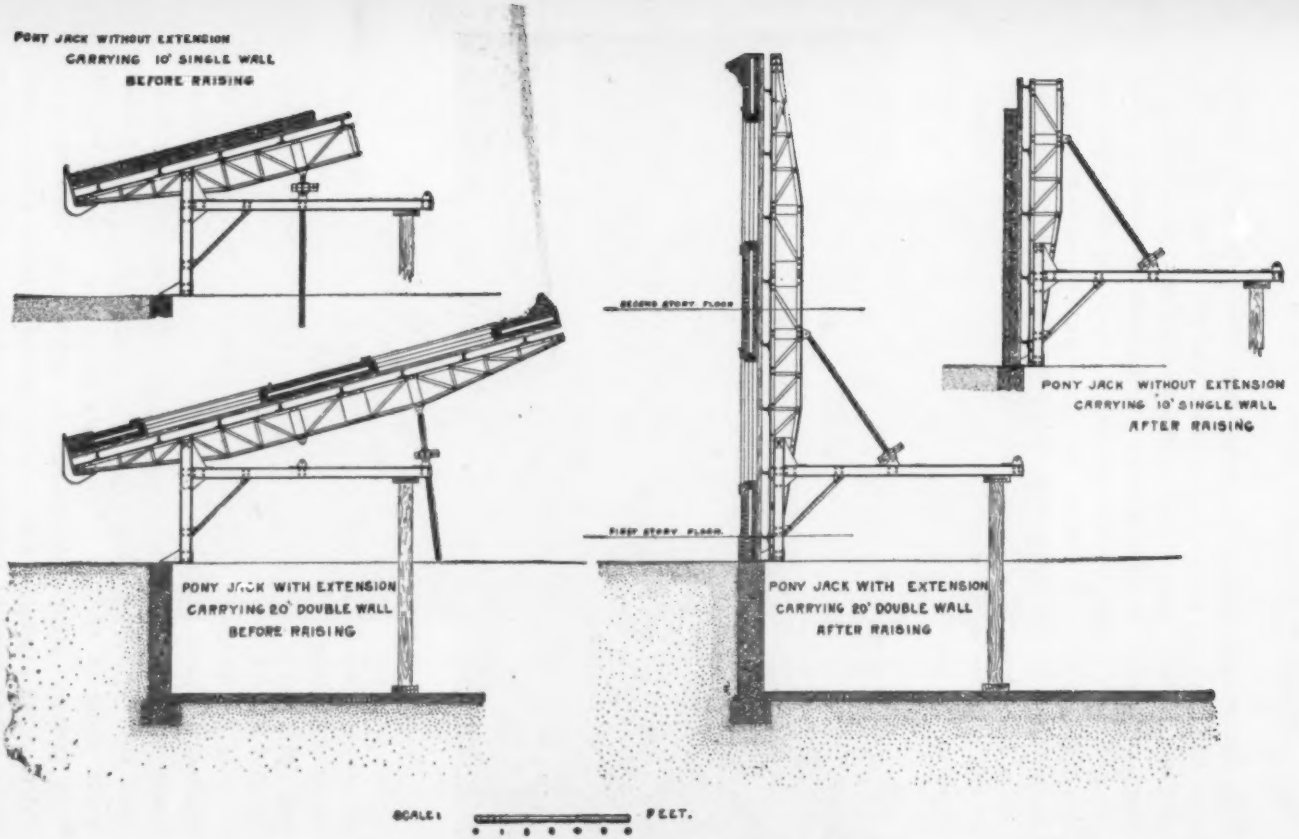

FIG. 5.—WALL RAISING JACK. LIMIT OF HEIGHT, PONY SIZE 20 FEET, STANDARD 30 FEET, JUMBO 40 FEET.

that the entire construction being done within the building line we could erect one story, put the floor on above it, and going upon that second floor, put up the next story, the next floor, the next story, and so on as high or higher than could be done with any other form of concrete construction. I say higher because in this form of construction we can place our reinforcement more accurately and so make the construction stronger and lighter. There is no building of false walls bellying out under the weight of the concrete pressing against them; no poking down between them of the reinforcing rods, which we can lay exactly in place

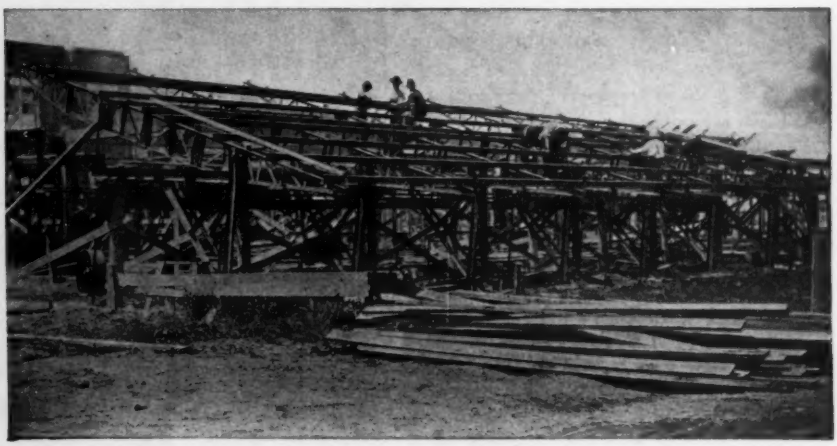

FIG. 6.—SETTING UP JACKS FOR THE WALL MOLD.

as on an open floor; no faults of surface where inefficient or careless tamping has failed to fill or bellied out the molds, for our outer surface is always face up, readily accessible for any desired surface finish or ornamentation.

Of the buildings that have been erected that which has attracted the most attention is the Mess Hall at the rifle range, Camp Perry, Ohio (see Fig. 2). It is 195 ft. long by 120 ft. wide over all, 27 ft. high, divided into two stories of marble white concrete surface. Why this particular building should have attracted such attention and so much more comment than others is not known. It has some features peculiar to itself and lacks others equally valuable and successfully used in other

buildings. It has plain, single, solid walls, not the double air spaced walls which we can make with finished surfaces on both sides or ornamented without and within.

The process of constructing the walls of this building, details of which are shown in Figs. 3 and 4, was as follows:

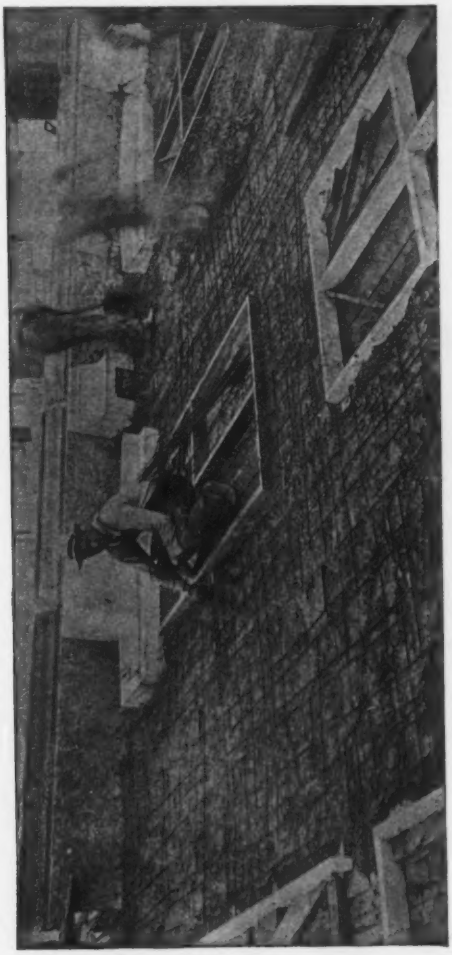

FIG. 7.—PLACING REINFORCEMENT ON 2 INCHES OF CONCRETE.

First a platform of 2-in. lumber was laid across steel beams supported by jacks (Figs. 5 and 6). The platform was about 3 ft. from the ground and lay inside the limits of the proposed

FIG. 8.—WHITE-FINISHING WALL ON FITTING PLATFORM.

building. Four-in. boards were set up on the four sides to complete the form. On the platform were placed the window frames and the reinforced concrete cornice, which was molded in 6-ft. sections, 3 ft. wide. In this case special ornamental window caps were required, and these were cast separately and placed in their proper positions on the platform. Then concrete made of one part cement, one and a half to two parts sand and four parts crushed stone, was poured upon the platform. After about 2 ins. of concrete had been laid, twisted steel rods for reinforcements were placed in both directions, 6 ins. apart, as shown in Fig. 7, and the balance of the concrete was poured on. The wall was made 4 ins. thick. As a facing, a cement mixture of one part white cement to one and a half parts white sand was laid on the surface, Fig. 8.

The work was allowed to stand forty-eight hours to give the material time to solidify, when preparations for lifting the wall to its permanent position were made. This was a comparatively simple task, most of the power being furnished by a 5 horsepower engine. It was connected by belting with the shaft under the platform operating the jack screws, and slowly the wall was tilted into position, Fig. 9. The platform supports were so placed that the foot of the wall swung to its position on the foundation at precisely the right line, and when the wall had assumed a vertical position, every line was plumb (Fig. 10). Five or six wood props braced to the window frames held the wall in position (Fig. 11), and the platform was taken away from the back and swung about for the construction of the next wall, at right angles to the first (Fig. 12). This operation was repeated until all the walls were up. The reinforcing rods were set to protrude at the edges of the walls, and when all the walls were in position, the rods interlocked at the corners of the structure. They were twisted together and an 8-in. board, the only false work used in the construction, was placed inside the corner. Here concrete was poured in, a joint made on the outside corner and the two walls thus bound together (Fig. 13).

As seen in Fig. 2, the mess hall is two stories in height and presents the appearance of massive construction, yet each wall was molded and set in place in less than three days' actual working time, although they have a height of 26 ft. The interior

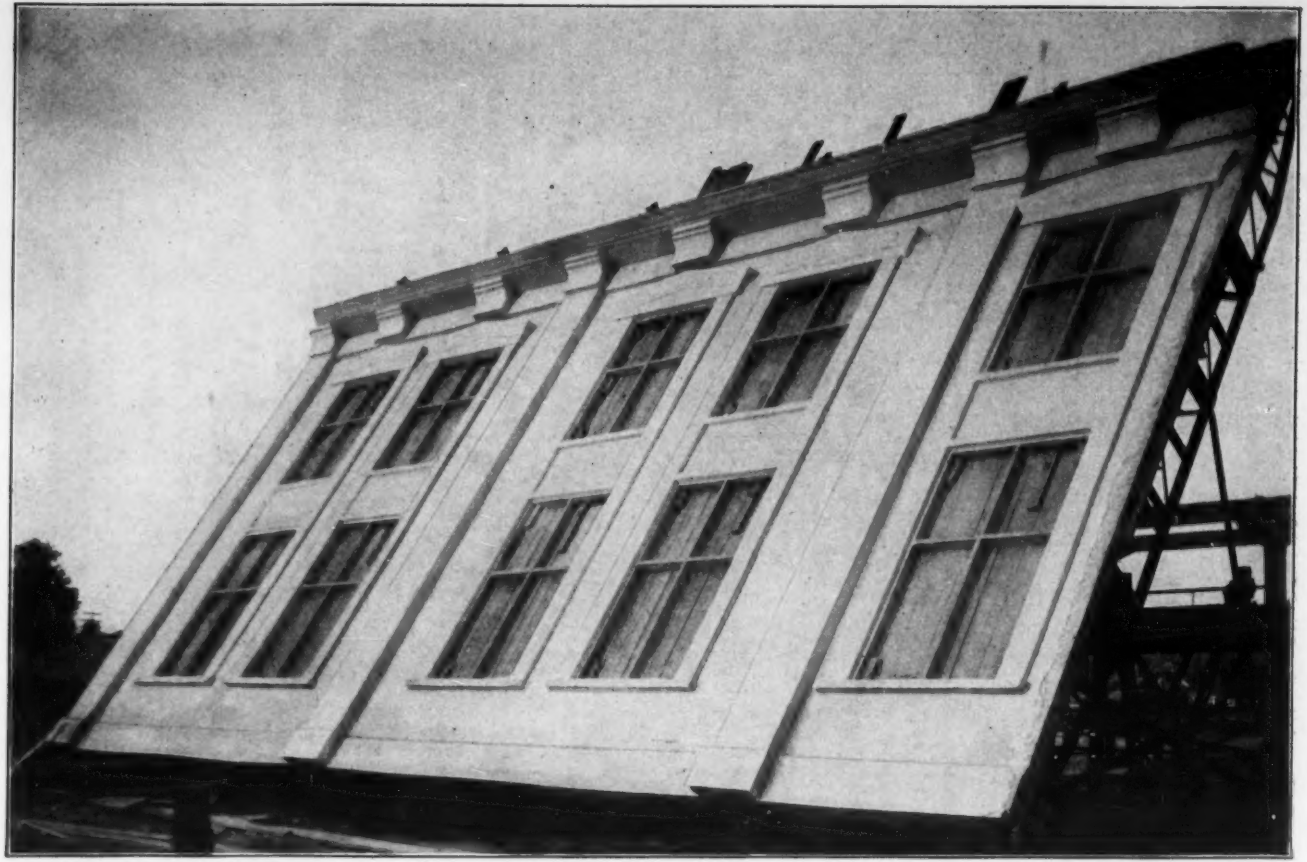

FIG. 9.—WALL RAISED HALF WAY.

construction was also of the same material, and here again an original plan was followed. Columns 8 ins. square and 10 ft. 8 ins. long were used in connection with girders 15 ft. in length and 8 by 12 ins. in thickness. Their reinforcement consisted of 16 ¼-in. steel rods to each member. Upon these girders were placed the floor slabs 3 ft. wide and 2½ ins. thick. Those of the first floor are reinforced with ¼-in. twisted bars, both ways, 6 ins. apart; the second floor slabs have similar reinforcement, 4 ins. apart. The slabs were molded in the following manner: On a bed of sand four stringers were set, having holes to receive the steel rods that protruded about 6 ins. on all sides of the finished slab. The concrete was poured in very wet and tamped but little. Ten minutes after the first slab was molded a sheet of heavy paper was spread on it, a new form placed on top and a second slab rested over the first. When the slabs were completed they were left to solidify and did not have to be handled again until placed in the floor.

In the floor the reinforcing bars of the slabs interweave at all sides. A board was placed under each joint and concrete poured in, forming a perfecting bond. In this, as in all similar cases on this work, the hard concrete was thoroughly wet before the cement mortar for the joint was applied. With the joint, each slab is 42 ins. wide. After the slabs were laid they were moistened and a top coat of concrete spread over the entire floor, bringing the thickness up to 6 ins. This has been termed the unit system of construction, but another method adopted was to mold the supports on the ground, then set them in place according to the plan sometimes followed in setting steel columns. By the method described no delay ensued in construction, and no party of workmen was obliged to wait upon others engaged on the building.

How far this system can be employed in building construction is an interesting question. Apparently it could be utilized in wall formations of much larger dimensions than those described, provided the adjustable framework for supporting the wall is of sufficient strength to give equal resistance to all portions of the load while being raised. As the lifting capacity of the jack can be increased to meet any weight which may be placed

FIG. 9.—WALL RAISED HALF WAY.

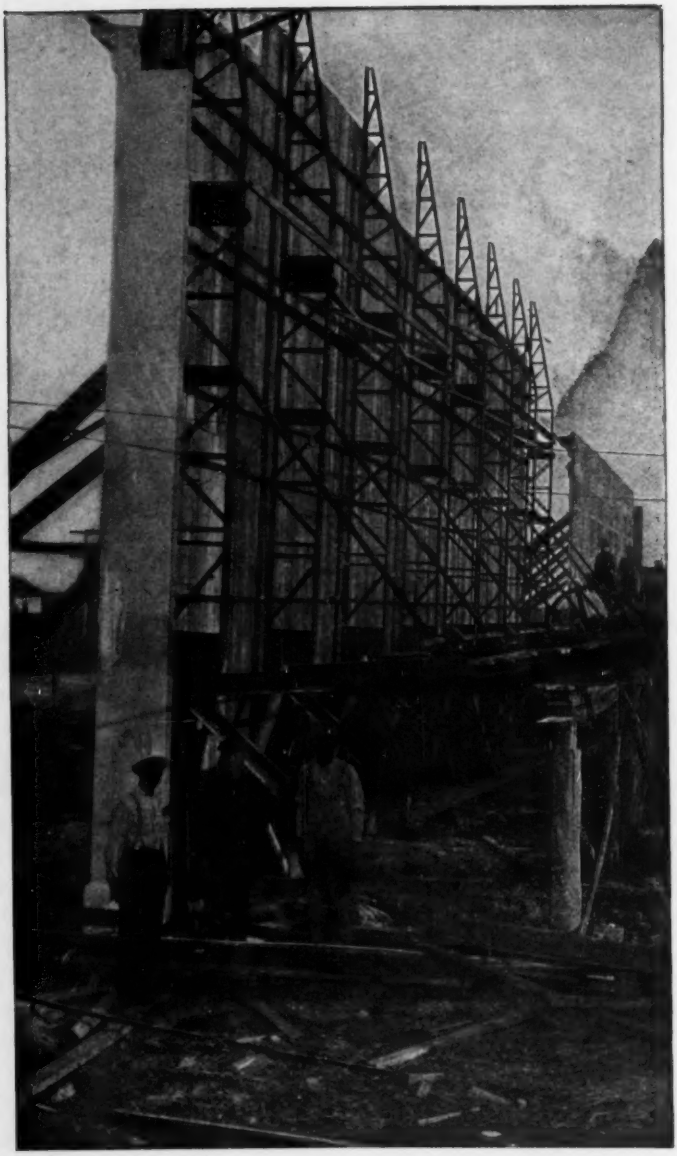

FIG. 10.—REAR VIEW OF WALL IN VERTICAL POSITION.

upon it, and the mechanical power can be suited to all the requirements, it would seem as if concrete buildings of much larger dimensions could be literally molded upon the ground even to the ornaments of the exterior and much of the interior framework, for if a wall is too large to be cast, so to speak, in one section, it can be formed in parts and then raised upon its permanent site.

Where this plan of erection can be successfully accomplished without affecting the strength of wall or putting undue stress on the work it possesses many advantages that are apparent —not merely in time saving, but in labor saving, also in curtailing the space usually required in building operations, so valuable in large cities. In the erection of a frame, brick or stone structure much of the time required is to lay up the walls piece by piece. All of the material must be elevated and transferred to the workmen. This represents far more time than that employed in the actual labor on the undertaking, while expense of conveying material is a large item of the contract. It is also evident that a wall or other portion of a structure can be completed more thoroughly when on the ground than from the aerial scaffold, since it is more accessible and far more men can work upon it to advantage, while each can accomplish more than he can by the ordinary process.

The practicability of molding a building on the ground, then raising and assembling the completed structure, is admitted by United States engineers, who have examined the work at Camp Perry with the view of employing the method in military service and have given it their official approval. Col. O. B. Parsons, State Engineer of Ohio, gives his opinion as follows:

> As regards the construction, I would say that I am convinced that it is both practical and economical, inasmuch as it does away with an untold waste of lumber and admits of a much stronger wall being built with less material. Practically all the lumber that is used are the planks on which the walls are molded, and they are used over and over without being cut or nailed. In constructing a wall in this way the mixture does not separate as while being poured from the top of a building, and there is also a great advantage in finishing, as one man will finish more than a half dozen while on a scaffold, do better work, and there is no trouble in bonding, as the surface is put on before the other material is dry.

FIG. 11.—CLOSING UP END WALL. TWO SECTIONS OF MAIN FRONT WALL, GAP FOR FRONT ENTRANCE WING. CAMP PERRY.

At Camp Perry this plan of erection is being employed in another interesting way. A wall for supporting rifle targets was included in the plans. It is also formed of concrete, but all of it is composed on the ground in sections, no less than 130 ft. in length. These are, of course, molded upon framework located at the site of the wall, which is 10 ft. high and 6 ins. thick. Consequently when a part of the barrier is set in place it is necessary to lift all this mass of concrete at one time, but the system of jacks supporting the adjustable framework has been efficient for the purpose.

Figs. 14 and 15 show examples of buildings constructed by this method.

In Chicago, thirty years ago, the building up of a subdivision with small cheap houses was a profitable business, but the increase in the prices of land, lumber and labor, together with the decrease in the quality of the lumber and the labor, and the growth of competition, has resulted in a condition where the owners of a subdivision have been building houses without profit in order to sell their lots.

On the other hand the high cost of the simplest of houses is working hardship on the workingmen. They no longer buy houses as they used to do. They rent, and if they do buy a home within their means it is of such flimsy structure that when their mortgage comes due the house has so deteriorated that it is no longer worth the cost of the mortgage. There are many houses for sale in Chicago for the cost of the mortgage or less for no other reason than material depreciation.

Now this is what this method of building can do for the poor workingman, and in many cases the still poorer owners of large tracts of vacant land.

It will enable us to build a comfortable small house of half a dozen rooms at a price well within an ordinary workingman's income, which will not only outlast the period of his installment contract and mortgage, but should outlast any house of brick or stone and wood ever built, a house on which little or no insurance need be carried and which will be in every way a better dwelling, more artistic, more comfortable, damp proof and sanitary; cooler in summer, warmer in winter and more economically heated.

While it is true that with the limited supply of skilled workers in concrete and the ready supply of skilled bricklayers, we

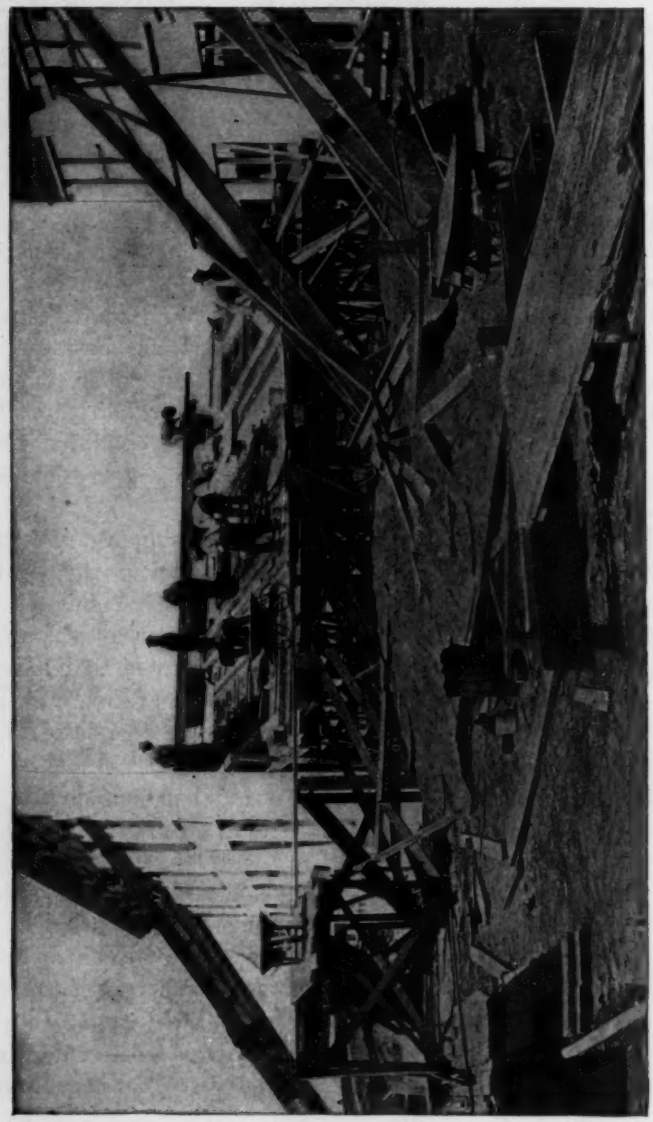

FIG. 12.—TWO WALLS IN POSITION. INTERSECTING WALL UNDER CONSTRUCTION.

cannot yet build a single small building of concrete much, if any, cheaper than of brick, yet we can compete with brick if we build

a number of houses a block at a time by this system. For the method enables us to cast a dozen house fronts in our monolithic wall 300 ft. long and raise them all to their erect position in one operation. If these houses are so designed that their rear walls are in line, their rear walls can be raised the same way.

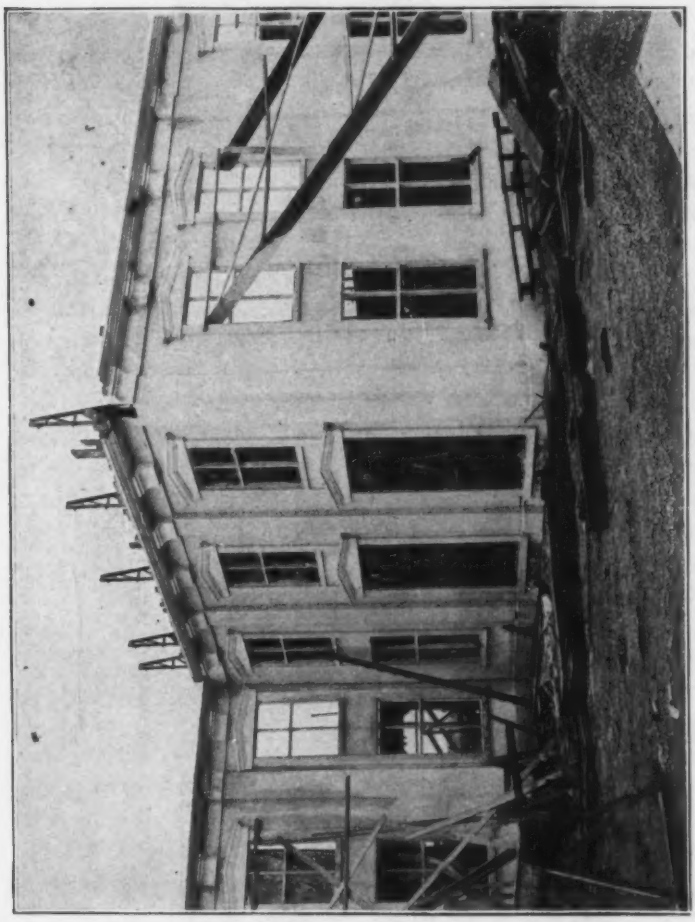

FIG. 13.—CROSS WALL CONNECTING KITCHEN TO MAIN WALL, JUST RAISED, READY TO STRIP OFF WOOD BACKING AND JACKS. CAMP PERRY MESS HALL.

With the party walls, floors and partitions set in place the concrete roof is but a simple modification of our floor construction, or the carpenter can furnish the stairways, doors and floors for people who are not yet fond of concrete floors in their living rooms and chambers.

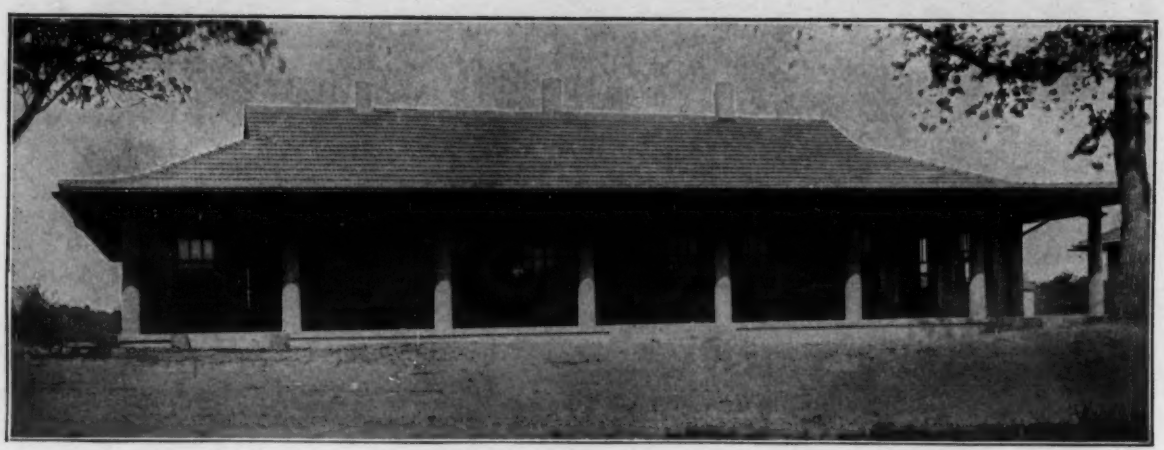

FIG. 14.—SOLDIER BARRACKS, TYPE ORDERED BY UNITED STATES GOVERNMENT.

As for the chimneys, they are cast on the party walls while lying flat before raising at a great saving over the cost of a brick chimney.

Such a house necessitates a lot of no greater width than the house, but if more yard room is desired the land owner can subdivide into deeper lots. I am subdividing for such houses into lots 25 x 200 ft., as against 25 x 125 ft., the ordinary lot size in my city. By this means I give each house as much back yard or garden room as an ordinary lot of 50 ft. front, which is there considered of ample size for any ordinary dwelling in the suburbs.

I have with me for the inspection of anyone interested in this matter a colored sketch of the front elevation of a block of twelve such houses, designed by Mr. Samuel M. Crowen, an architect of Chicago.

In the front elevation of the houses he has succeeded in departing entirely from imitations of the architectural styles belonging to stone, wood, brick and the old materials, and has produced a design artistically adapted to concrete.

The body of the wall may be natural cement color, of rough cast surface, all in one undivided, unpaneled wall, to each house front, either smoothed or rock finished in imitation of chiseled or uncut stone or blocked out like brick or paneled like wood.

The window and door caps and trimmings may be of white concrete in harmonious contrast with the cement colored body wall. The ornaments may be of molded concrete, inlaid ornamental tile, or free-hand plastic work, properly in accord with the plastic material it sets off wherein the exact mechanical lines, angles, circles and geometrical ornamentation should be omitted.

This particular feature of Mr. Crowen's designs is one which other architects would do well to take note of, for a concrete designer should not attempt imitation of other styles, but initiation of a style all its own, belonging particularly to and in accord with the plastic character of the building material used, the only building material of its kind and soon to be the most commonly used of all.

These houses are two stories high, 25 ft. wide and 30 ft. deep, each has six large rooms, a front hall stairway and bathroom, or any similar arrangement of rooms desired by the tenant

or buyer. All rooms are lighted by windows looking on the street or back yard and there is no cellar nor attic. These houses are heated by stove or fireplace, and built in this way should sell within a workingman's income and yet at a good, round old-fashioned margin of profit to the builder.

This block will be built by first erecting the front wall of twelve house fronts in one piece, inclusive of coping, cornice and gutter at the top and the entire foundation wall at the bottom, for these houses are going on ground where the rock comes within a foot or two of the grass roots. They are so designed

FIG. 15.—STORE BUILDING, 30 X 40 FEET, WITH CELLAR, NEAR KENOSHA, WIS.

that the rear walls for the entire block of twelve houses, 300 ft. long, is all one wall cast in one piece with its door frames, window casings, roof drain and foundation wall before tipped up into permanent position. The casting and erection of end walls, party walls and partitions is a similar operation, and the concrete roof is made after the manner of our floor construction, with a waterproof surface troweled on top of it.

Blocks of houses of the type mentioned for workingmen and larger, more ornate and costlier ones for people better off, in the same block arrangement, are beyond competition in other building material.

Naturally, we are glad to give anyone the fullest benefit of our information and experience about our method and bring nearer that day already approaching with a speed, as modern as automobiles and airships, when by our method or some other perhaps better, we take the latest great step in civilized structure building and make all buildings of this marvelous new material in the use of which artist, architect and artisan alike shall have gained the knowledge and skill they now have of the older forms, and all our habitations become more beautiful, more sanitary, more economical, more comfortable and more enduring than any that the world has ever seen.

COLD STORAGE WAREHOUSES OF REINFORCED CONCRETE CONSTRUCTION.

By J. P. H. Perry.*

The purpose of this paper is to present the different methods of insulating buildings for cold storage or similar purposes and to give also an idea of the adaptability of reinforced concrete to this type of structure. Up to the present time there has been practically nothing written on the use of reinforced concrete in connection with insulation, and there are undoubtedly many promoters of storage plants who have no proper conception of the advantages offered by concrete for buildings of this kind.

As the necessity for cold storage plants has developed, attention has been given the insulation question and the materials which would fulfill the requirements have been studied. It was soon apparent that insulating materials must possess the following properties: Low conductivity, minimum capillary attraction, low affinity for moisture, fireproofness, and minimum tendency to continue combustion internally after the external flame is extinguished. In addition to the above requirements, the insulating substance must not be such as to pack down readily and leave air space at the top of the filled compartment. Furthermore, the insulation should be durable, cheap and easily installed. In considering insulating materials, it must be understood that their worst enemy is atmospheric moisture, which must be kept out of the construction to obtain permanent satisfactory results. In cold storage work artificial conditions are set up. Difference in temperature means difference in pressure, and as long as the refrigeration is maintained the warm atmosphere is pressing in through the walls everywhere. The resistant materials must be such as to resist moisture rather than receive it.

In the early days of artificial refrigeration, which dates back not much over forty years, it was the almost universal belief

* Turner Construction Company, New York, N. Y.

that the most effective insulation consisted of air spaces. It was recognized that the easiest way to prevent the circulation of the air was by filling the air space with some substance which would break it up. Thus in the primitive storage plants and in icehouses the walls were insulated by erecting studs and sheeting both sides to produce an inner and an outer wall and filling the space between with shavings or sawdust. Floors and ceilings were protected in the same manner, the filling material being packed between the joists. When it was realized that such a deadener (as the filling material is known) would soon collect moisture and lose nearly all its efficiency, besides settling and leaving free air spaces, the breaking up of the air spaces was effected by means of "boards and air spaces" formed by alternate sets of furring strips and matched boarding in several layers as the temperatures to be maintained required.

The next step forward in the development of the art of insulation was the use of mineral wool. This material is made by subjecting molten furnace slag to a steam jet. It is used for a filler the same as sawdust and possesses many advantages over the earlier materials. It is fireproof and does not tend to pack to the same extent.

Soon after the introduction of mineral wool use was made of granulated cork. As a deadener it was light in weight, of low conductivity, and with very slight capillary attraction. It possessed some tendency to settle and leave free air spaces.

As the study of the cold storage progressed, a radical change was brought about in the theory and practice of the insulation installation. Until about ten years ago dead air was the basis of all insulation. It became evident that air spaces, even though filled with deadening materials, left a great deal to be desired in matters of efficiency, durability and safety. The air in the spaces was not dead; instead, it circulated through voids in the filling material and in so doing carried moisture to all parts of the insulation. Even more important in throwing the balance against this method of protection were its non-fireproof qualities. It would be difficult to imagine a more grave fire risk than wooden walls filled with sawdust or shavings. Brick buildings insulated along the same lines were proved serious fire hazards, so much so in fact that the insurance companies were forced in

their own protection to make high rates on cold storage plants, so numerous were the bad fires in this type of building.

The modern theory of successful insulation is based upon entrapped air, air that is actually dead. This means that the air must be in sealed spaces and that the spaces must be minutely small, otherwise the essential idea of "still air" is overthrown. The insulation must depend for its entrapped air upon the interstices or cells of the material employed rather than upon alternate layers of solid insulation and air spaces.

This new principle of insulation, which does away with double walls with air spaces between, has brought into vogue solid insulation. In this type the protection consists of layers or blocks of various materials set in Portland or pitch cement directly against brick or concrete walls and protected on the inside surface by plaster or tile. The space occupied by solid insulation is much less than that utilized by the older construction. If a fireproof or slow-burning material be used in making the insulation, the fire risk is greatly reduced.

The materials available for this so-called "solid" method of insulation are chiefly cork and compressed mineral wool blocks called "lith."

Cork, by virtue of its natural state and the apparent use for which nature intended it, lends itself admirably to insulating purposes. In cold storage work cork is efficient as a non-conductor of heat, is free from capillary attraction and has no tendency to absorb moisture freely. When used as cork boards it is granulated, compressed in iron molds and baked while under pressure, its own natural gum being liquefied by the heat and uniting the granules into solid blocks. These have fair structural strength and are quite fireproof.

Lith is made from rock fiber mineral wool and degummed flax fiber. In the process of manufacturing the settling propensities of the mineral wool are removed and the product given structural strength by the degummed flax fiber. The finished material is a strong, light, durable board. It consists of many minute cells which confine air with the least possible chance for circulation. Lith is fairly fireproof, a good non-conductor of heat, and compares, when cost is considered, favorably with cork board.

In discussing the practical application of insulation the different methods will be considered in detail in their order of use, taking up first the wall construction, then considering the floors and roofs.

One of the earliest forms of insulation to be generally adopted is shown in Fig. 1. It is still in frequent use, particularly for natural ice storage houses. Briefly, the insulation consists

FIG. 1.*

of constructing a hollow wall with joists about 3 x 12 in. spaced 24 in. on centers and sheathed on both sides with ⅞ or 1-in. boards. Sometimes these are clap-boarded on the outside to protect the air space from the weather. Occasionally this is not thought necessary. The space between the two sheathings is filled with shavings or sawdust, most often the latter. Although this form of insulation can be installed cheaply and

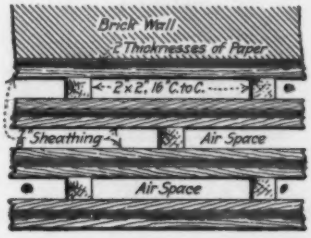

FIG. 2.

rapidly, it constitutes a grave fire risk, and owing to the tendency of the sawdust packing to absorb moisture rapidly, it is not permanent.

*Acknowledgment is made to the *Engineering News* for the line cuts used in this paper.

Another method which is similar and yet a little more scientific, and which is used to a considerable extent by one of the largest firms of meat packers in this country, is shown in Fig. 2. A brick or concrete exterior wall is constructed of standard thickness. Against this are placed two layers of waterproofing paper, then 7/8-in. sheathing, preferably tongue-and-groove. A 2-in. air space is then formed by 2 x 2-in. furring strips about 16 in. on centers. On these is nailed another layer

FIG. 3.

of 7/8-in. sheathing against which are placed two thicknesses of waterproof paper. Then another thickness of 7/8-in. sheathing against which are placed two thicknesses of waterproof paper. Then another thickness of 7/8-in. sheathing, and a second air space is formed similar to the first. The alternation of waterproof paper, sheathing, air spaces and sheathing is continued to the thickness deemed sufficient to hold the storage rooms at the

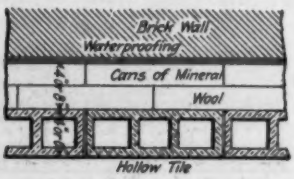

FIG. 4.

desired temperature. This insulation can be installed cheaply, and in some cases has been found to be efficient. The chief point against it is the fire risk it creates. Its low initial cost is the main argument in its favor.

The structural details commonly employed in connection with installations of mineral wool are shown in Fig. 3. The interior bracing wall is generally of plaster blocks or hollow tile laid in cement mortar. Owing to the tendency of the packing

to settle, unusual care has to be exercised in placing, to prevent arch action.

One way of utilizing the advantages of mineral wool and at the same time getting away from its settling has been worked out by a large Boston cold storage company. The details are shown in Fig. 4. In this installation galvanized iron cans are constructed, 2 in. in thickness and just large enough to hold a

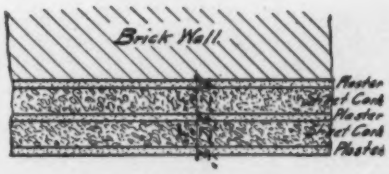

FIG. 5.

sheet of mineral wool. These, after being filled, are soldered tight and placed in the wall as in any insulating, the cans breaking joints and all joints being sealed with Portland cement mortar. In this manner the mineral wool is protected from moisture and also from settling. It would seem, however, that there must be a loss through the cans where they join. It is nevertheless stated that this form of insulation is very efficient and that it has given satisfaction. Its cost is somewhat higher than the other mineral wool installations.

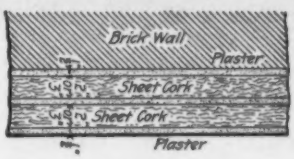

FIG. 6.

The structural features employed when ground or granulated cork is used are illustrated in Fig. 5. The exterior wall is built of concrete, brick or terra cotta, and damp-proofed with any one of the legion of waterproofing processes. At a distance dependent upon the amount of insulation required, an inner wall of concrete or tile is put up and the intervening space filled with ground cork. This form of insulation gives high efficiency and has considerable

durability. Its cost rather exceeds mineral wool. The chief disadvantages are its settling tendencies and its readiness to run out of any opening accidentally made in the supporting walls.

Coming now to solid insulation, the structural details are covered in the main by Fig. 6. As already indicated, either sheet cork or lith may be used. Against the outer wall of standard construction is placed a sheet of cork 2 or 3 in. thick set in Portland cement about ½ in. thick. Against this first layer of cork the second is applied with another ½ in. cement coat. The joints between the cork boards are broken both horizontally and

FIG. 7.—CEILING INSULATION LAID ON FORMS READY FOR CONCRETING.

vertically. The inner surface of the insulation is given a ½-in. plaster coat with sanitary finish. Generally the inside of the building wall is given a waterproof coat before the first cement binder is applied. This system is very efficient, is not attacked by moisture, is very durable and, generally speaking, fireproof. It occupies minimum space. Its disadvantage is its high initial cost.

Figs. 7 and 8 show cork-board insulation being applied to ceiling and walls. Fig. 9 gives a construction view of the plant of the Merchants' Ice and Cold Storage Company, Cincinnati, O.

The question of interior walls and partitions in so far as

their insulation is concerned does not present any important differences from the exterior wall protection except that the two sides of the insulating material are of necessity both of tile or block or thin concrete. In the ordinary case the temperatures on the opposite sides of interior partitions do not range as wide apart as with the enclosing walls of the building. The importance of properly protecting stair and elevator walls with insulated partitions will be discussed later.

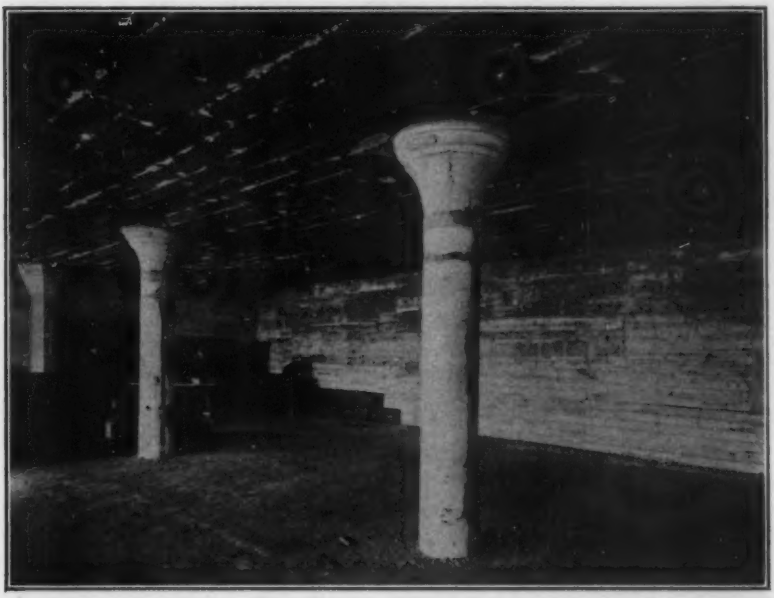

FIG. 8.—PLACING CORK BOARD WALL INSULATION IN PLANT OF THE MERCHANTS' ICE AND COLD STORAGE COMPANY, CINCINNATI, O. CEILING INSULATION IN PLACE.

The design of the structural portions of cold storage buildings is of prime importance. The usual type of construction having walls and floors joining is subject to serious loss at these points. The most recent practice in artificial refrigeration buildings erects the frame of the structure independent of the enclosing walls, which latter are made entirely self-supporting and separate from all floorbeams and columns. This scheme increases the efficiency of the insulation sufficiently to make it worth while. Fig. 10 gives roughly the main features to be ob-

tained in this design. The curtain wall being self-supporting permits carrying the insulation by the face of the interior columns, beams, girders and slabs, thereby securing continuous insulation. The exterior or curtain wall would be tied to the structural frame by steel anchors connecting at the floor lines. To eliminate as far as possible a loss through these ties, they should be wrapped with hair felt or similar material. In any event their combined cross sectional area would constitute but

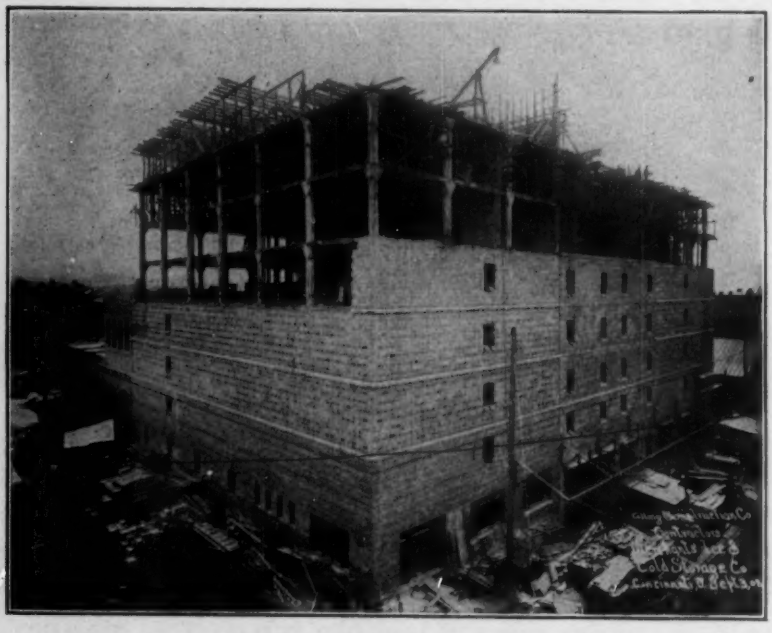

FIG. 9.—CONSTRUCTION VIEW OF PLANT OF THE MERCHANTS' ICE AND COLD STORAGE COMPANY, CINCINNATI, O.

a very small fraction of one per cent of the total wall surface, and their conductivity value would, as compared to the loss through I-beams resting on bearing walls, be at a minimum.

The problem of insulating the conventional type of building has been solved as far as the elemental conditions will allow by the method shown in Fig. 11. This undoubtedly is the lowest in cost. The insulation runs from floor to floor, stopping at the underside of the beams and the floor arches. The beams and floor, of course, carry on into the wall and cannot be protected.

Another and better method is to construct floors only up to the inner line of the insulating partition (see Fig. 12). The beams and girders rest on the bearing walls or on the wall columns or wall girders, with consequent loss, but the insulation prevents the entire floor section from conducting to the walls.

As to whether or not the floors of a cold storage building should be insulated is an open question. Some plants are designed so that the building is divided into several sections, and the same temperature maintained on all floors in any one section. Where this idea is followed the individual floors are not insulated. Unless, however, some proposition similar to this be adopted, it is essential that floors be insulated.

The insulating of the basement floor or ground floor is subject to a wide difference of opinion. Some very good authorities claim that unless the room of which the ground floor is

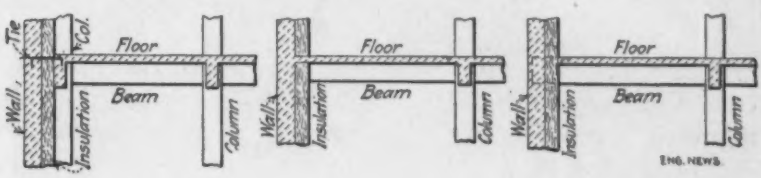

FIG. 10. FIG. 11. FIG. 12.

the base is to be used as a freezer, it is unnecessary to insulate the ground floor other than by a bed of cinders and the concrete floor laid on top. As the earth remains practically constant in temperature at about 55° Fahr., and is a fairly good conductor as well, it would seem that there would be a constant loss unless the floor is insulated with the same care as the walls. It seems advisable, therefore, to construct a base floor of 3 in. of concrete placed directly on the ground or on a bed of cinders. On top of this lay a waterproofing coat and then apply the insulation, either lith, mineral wool or sheet cork, from 2 to 6 in. thick, depending on requirements. The insulation should be given a mop coat of waterproofing material and covered with 5 ins. of concrete with 1 in. of finish. It would be possible to use a thinner concrete slab by reinforcing it with a small amount of steel. Fig. 13 shows this construction. In most instances it would be well to reinforce the ground floor, as the movement

of heavy hand trucks or the dropping of barrels to the floor would tend to crack a plain concrete floor, with resulting loss of protection.

Self-supporting floors where insulation is necessary are treated in much the same manner as the ground floor. On the reinforced concrete or hollow tile bearing slab is placed from 2 to 6 in. of lith, mineral wool or sheet cork (see Fig. 14). This should be laid in pitch or some other waterproofing compound

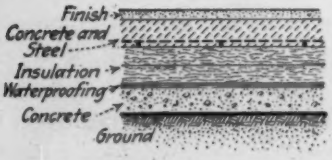

FIG. 13.

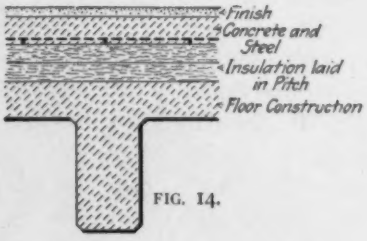

FIG. 14.

to protect it. On top of the insulation is placed the 3-in. concrete floor having 1 in. finish. This top slab is reinforced lightly to prevent cracking of any character. Where the insulation consists of wood and paper, the construction is similar to the walls; only the top concrete is given a wearing surface.

Where the insulated room comes next to the roof the

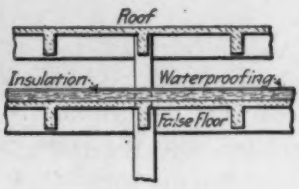

FIG. 15.

practice has been of two general kinds, one using an air chamber between the roof and the ceiling of the top story, and the other insulating the roof itself.

The former method is varied in its applications. In some installations an attic 3 or 4 ft. high has been built and in others a hung ceiling has been specified. With either type the ceiling

is insulated with any one of the systems described for protecting walls; that is, sawdust, ground cork or mineral wool can be laid on the attic or air chamber floor (which is the ceiling of the top story room) and protected with a waterproofing coat. Lith or cork boards are usually placed in pitch or asphalt and covered with asphalt paper. Fig. 15 shows this type of roof protection, the detail calling for a specially built-in attic floor. Figs. 16 and 17 show construction and completed views of plant of the Eastern States Refrigerating Company, Hoboken, N. J.

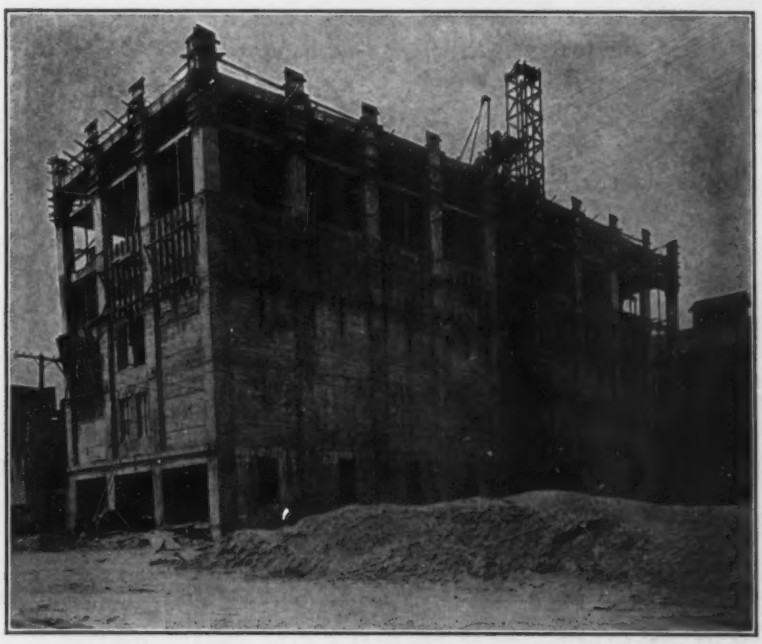

FIG. 16.—CONSTRUCTION VIEW, SHOWING ATTIC FOR INSULATION OF ROOF.

The insulating of the roof can be handled by placing the insulation directly on the roof construction. In this case the insulation should be preferably of sheet cork or lith laid in a waterproofing substance. On top of the sheet cork is then placed from 1 to 2 in. of concrete as a protection, and then the regular roof waterproofing is applied. The only serious objection to

laying the insulation directly on the roof is that in event of a leak in the roofing developing, the percolation of water would spread through the insulating material and show on the ceiling at some point, possibly quite a distance from the original leak. This would require ripping up a considerable area of the insulation and roofing in order to locate the break, whereas in the hung ceiling method the roof leak could be detected accurately and at much less expense than in the former case.

FIG. 17.—PLANT OF EASTERN STATES REFRIGERATING COMPANY, HOBOKEN, N. J. A TYPICAL COLD STORAGE PLANT.

Where the temperatures maintained in the rooms in successive stories are not the same, it is necessary to insulate the columns, otherwise loss will occur rapidly. This is done in a manner similar to the insulation of the walls. The only special point to be watched is the joining of the floor and column insulation so that it is made continuous.

When buildings are divided into separate fire risks by fire walls, the conduction from one floor risk to the other through the continuous floor can best be avoided by carrying each section or risk on its own columns instead of using a common column between the two. This adds very little to the cost of the building, allows a continuous fill of insulating material between each fire risk, and not only prevents conduction through the columns but also prevents conduction through the floor by reason of the insulation passing by the ends of the beams. This same idea applies favorably to the detailing of elevator shafts and stair walls. If the framing of these shaftways is exposed, sweating or frosting may be expected from each floor. Sufficient clearance should be provided, therefore, to allow carrying up a separate tile or concrete wall inside the shaft and tied to the skeleton of the building as few times as consistent with safety. Between this inner partition and the shaft lining itself a continuous band of insulation should be provided.

Fig. 18 shows cold storage warehouse of the J. C. Roth Packing Company, Cincinnati, O., of reinforced concrete throughout, with hollow tile walls plastered.

The doors and windows in cold storage plants are a serious problem. Of the latter there are generally very few, if any. Of doors, however, there are a quite number always necessary. Wherever any openings are required in the partitions or in the fire walls or from the receiving rooms to the refrigerating chambers, double fireproof doors have to be installed. The underwriters have approved making one of these doors a swing refrigerator door covered with galvanized iron or tin, in accordance with the standard firedoor specifications, and the other door an ordinary fireproof door held open with a fusible link. The best types of refrigerator doors have two seals of contact between the door and the frame. Self-tightening fasteners and adjustable spring hinges keep the door tight, making an airtight opening, which tends to prevent the spread of fire or the loss of refrigeration through the joints. The doors themselves are hollow, the sides being of wood metal-covered, with an insulating material filling the air space (see Fig. 19).

The cold storage building windows are designed along the same lines as the doors. The glazing consists of as many

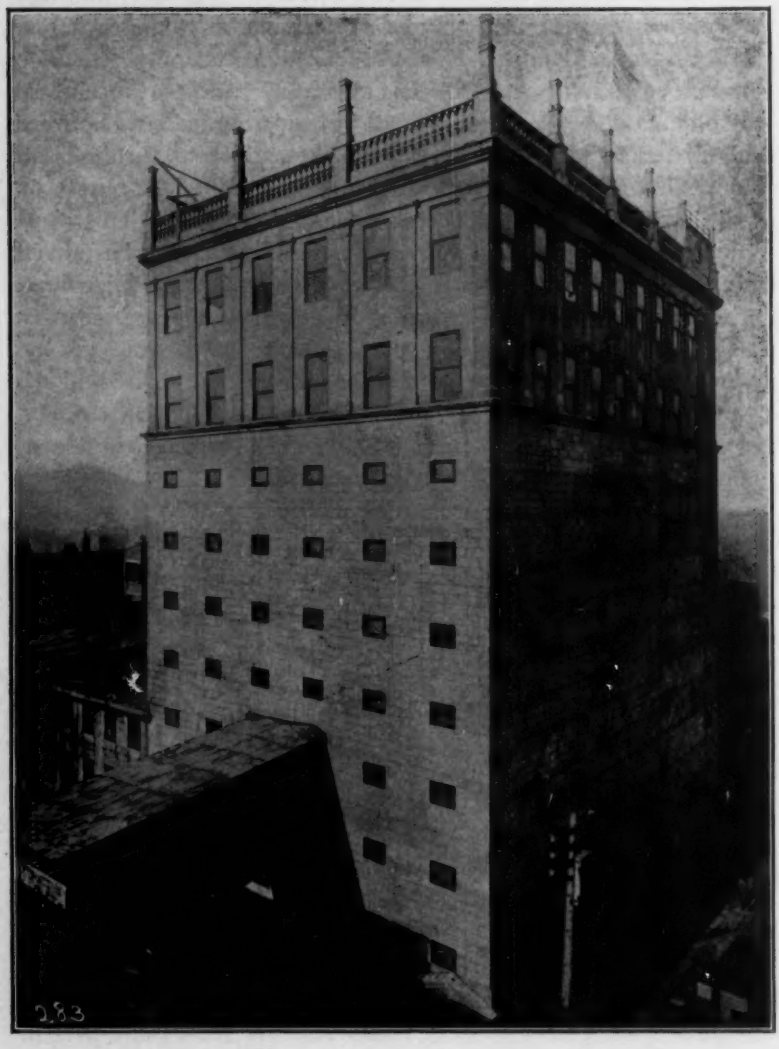

FIG. 18.—COLD STORAGE WAREHOUSE OF J. C. ROTH PACKING COMPANY, CINCINNATI, O. REINFORCED CONCRETE THROUGHOUT, WITH HOLLOW TILE WALLS PLASTERED.

thicknesses as conditions require. All the glass is nested in one sash, which is hung with adjustable spring hinges and held closed by a special fastener. The outside thickness of glass is generally reinforced with wire. The double seals of contact make an efficient joint.

One of the main topics of discussion on this subject of insulation of cold storage buildings is the question of fireproofness and the conditions which attract the interest of the underwriters and influence their verdict as expressed in the rates they are willing to quote. On cold storage buildings with solid insulation, fireproofed skeleton, and concrete or brick walls, the fire risk is at a minimum. As noted at the beginning of this paper, the insurance companies have been obliged to be very severe on the ordinary cold storage proposition because in the early day with wood walls and filled air spaces ideal fire conditions were established. In the more modern buildings, even, it was felt that

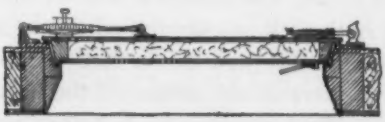

FIG 19.

the insulation increased the fire hazard owing possibly to the opportunity offered a fire to smolder in the walls. But with the best up-to-date practice the insulation is really a help in making the properly-designed cold storage building more fireproof. There are instances on record where cork board and similar insulating materials have withstood severe fires in a manner to compare favorably with terra cotta. The insulation, from the very reason for its existence, prevents heat from reaching the walls. In several fires it has been found that so little heat passed through the insulation to the walls that they were unimpaired. In other cases slow-burning constructions, with their heat-resistant insulation, have confined to single rooms fires which in the usual type of building would have spread from cellar to roof and gutted the structure.

The question of the relative efficiency of the different insulating materials is too complex and the information which can

be obtained is too partisan in source and character to permit of much being said about it in the limits of this paper. There is praiseworthy laboratory work being done at several of the great technical schools and one company engaged in the manufacture of an insulating material maintains in Pittsburg an experimental station which is carrying on investigations of value.

The majority of cold-storage plants up to the present time have been built of brick or stone, with structural steel frames and terra cotta or brick floors. There are, however, a considerable number of artificial refrigeration establishments in which reinforced concrete has played an important structural part. These are the more modern ones. Concrete success is apparent when such an authority in the refrigerating world as Mr. John E. Starr, of New York City, states that "another point may be mentioned which shows the great stability of reinforced concrete construction for beams, girders . . . floors. In the house . . . . at St. Paul the construction of the concrete work was commenced in the fall and continued through the winter . . . The refrigeration was turned on in hot weather, and the first floors refrigerated were in the center of the building at very low temperatures, ranging from zero to -5° and up to 35°. It will readily be seen that under these conditions the building was subjected to the most severe strains that could be conceived of in the way of expansion and contraction, and yet there was not a sign of a flaw or a crack in any column, girder, beam or floor, and this on a comparatively green building, which, of course, is growing stronger every day." When a statement such as this is made, the availability and the advantages of reinforced concrete for such construction may be considered as well established.

In addition to the ability of concrete to withstand the cracking which putting a building into a state of refrigeration sets up, its fireproof and waterproof qualities must be admitted; and the elimination of vibration in a reinforced concrete mill building, even under the most severe machinery movements, must have some bearing on the possibility of this material being best for cold-storage plants when vibration means unsettling insulation, cracking waterproofing and doing similar other damage. Taking into account also the load-sustaining properties of concrete, which

it is almost unnecessary to mention to those who know the substance at all, and regarding with a critical eye its permanence, which means elimination of repairs and maintenance charges, the unbeliever must acknowledge that reinforced concrete certainly is entitled to trial for cold-storage structures.

That it has been used in face of the sharp competition it has had to meet is due to the readiness with which it meets all specifications and the economy it effects when compared with other fireproof structures. Reinforced concrete buildings of reasonable size, that is, costing $60,000 and upward, can be and actually have been erected at costs running from 10 to 20 per cent. lower than the best bid received for steel construction on the same plans. On medium propositions concrete will not exceed first-class mill construction by more than 10 per cent., and in several instances where the estimated cost of the building has run over $150,000, the figures submitted by the concrete contractors have been slightly lower than those of the mill construction men.

For special construction necessitating long spans, irregular column spacing, unusually heavy loads, curtain walls, or like unique features, concrete is particularly well adapted, and under just such conditions has proved itself time and time again.

The insurance question, which is so much mooted among the cold-storage interests, has direct bearing on the use of reinforced concrete. Baltimore and San Francisco tested concrete and found it good. Individual fires like those in the Pacific Coast Borax Co.'s building in Bayonne, N. J., the Huyler Co.'s factory in New York City, and the Dayton Motor Car Works at Dayton, Ohio, showed the material under most trying fire conditions and demonstrated that the keen-sighted insurance men as typified by the Mutual companies are conservative when they offer to write the lowest rates on concrete buildings that have ever been written on similar structures, and still more so when they urge the adoption of reinforced concrete for all industrial buildings.

Table I is presented with the idea that it may be useful to reinforced concrete engineers and contractors in dealing with prospective builders of cold storage plants to refer to buildings

TABLE I.—PARTIAL LIST OF COLD STORAGE PLANTS OF REINFORCED CONCRETE CONSTRUCTION.

All buildings have concrete floors. b = basement; C = Concrete; S = Steel; M. C. = Mill Construction; B = Brick; T = Tile.

Location.	Owner's Name.	Used for	Year Built.	Size of Building.	No. of Stories.	Kind of Frame.	Kind of Walls.	Kind of Insulation.	Roof Insulation.
				Feet.					
Boston, Mass.	Quincy Market Cold Storage and Warehouse Co.	Cold storage, misc.	1908–09	155x55	10	C.	B.	Min. wool in cans.	Attic insul. floor.
Brooklyn, N. Y.	People's Hygienic Ice Co.	Ice storage	1907	90x60	1	"	C.	Cork	
Brooklyn, N. Y.	Fred. Loeser & Co.	Fur storage	1909	161,000 cu. ft.	2	"	"	"	
Canal Zone	Isthmian Canal Comm.	Cold storage	1908	.....	.....	"	"		
Chattanooga Tenn.	Crystal Ice Co.	" "	1905	90x70	4, b.	"	B.	Min. wool	None
Chicago, Ill.	Hately Cold Storage Co.	" "	1907–08	400x112	4	"	"	Lith.	Direct on roof.
Chicago, Ill.	North Am. Cold Storage Co.	" "	1904	165x165	16, b.	S.	"	"	
Cincinnati, Ohio	Fireproof Storage Co.	Fur storage	1906	.....	9, b.	C.	"	Cork board	
Cincinnati, Ohio	Merchants' Ice and Cold Storage Co.	Cold storage	1908–09	165x205	8, b.	"	T.	" "	
Cincinnati, Ohio	J. C. Roth Packing Co	" "	1908	80x100	10, b.	"	"	" "	
Cleveland, Ohio	Sheriff St. Market Co.	" "	1907–08	113x98	6, b.	"	"	" "	Attic insul. floor.
Detroit, Mich.	Murphy Cold Storage and Ice Co.	" "	.....	.....	10	S.	B.	Lith. and cork	" " "
Detroit, Mich.	A. Booth & Co.	" "	.....	.....	6, b.	C.	"	Lith.	" " "
Detroit, Mich.	People's Ice Co.	Ice plant	1906	90x60	3	"	T.	Cork	
Elmira, N. Y.	Hygeia Ice Co.	Cold storage	1909	140x53	6, b.	"	"	Lith.	" " "
Hoboken, N. J.	Eastern States Refrigerating Co.	" "	1906	140x50	5	"	C.	Gypsum block	" " "
Irvington, N. J.	Castles Ice Cream Co.	Ice cream mfg.	1908	169x44	3	"	T.	Cork	Direct on roof.
Jersey City, N. J.	Union Terminal Cold Storage Co.	Cold storage	1909	100x72	6, b.	"	B.	"	Attic insul. floor.
Louisville, Ky.	Fireproof Storage Co.	Fur storage	1908	42x150	8, b.	"	C.	Cork board	Direct on roof.
Memphis, Tenn.	Memphis Cold Storage Warehouse Co.	Cold storage	1907	240x64	9, b.	MC	B.	Lith.	None.
New York, 14th St.	August Silz	" "	.....	50x100	4	S.	C.	Min. wool	
New York, Bronx	Conran Bros.	" "	.....	200x50	1	"	"		
New York, Bronx	Swift & Co.	Refrigerating r'ms	.....	114,000 cu. ft.	.....	C.	"		
Provincetown, Mass.	Consolidated Weir Co.	Fish freezing	1907	100x50	5	"	C,b	Cork board	None.
Poughkeepsie, N. Y.	Hygeia Ice and Cold Storage Co.	Cold storage	1908	106x75	8	"	"	" "	
Richmond, Va.	W. C. Forbes	Meat cooler	1006	162x85	5	"	B C		
St. Louis, Mo.	Wm. J. Lemp Brewing Co.	Fermenting house	1907	106x70	6, b.	S.	B.	" "	Direct on roof.
St. Paul, Minn.	A. Booth & Co.	Cold storage	1906–07	110x90	9	C.	"	Lith. and cork	None.
Washington C. H., O.	C. H. Brownell & Sons.	" "	1902	110x40	.....	"	T.	Cork	Attic.
Waterbury, Conn.	Swift & Co.	Refrigerating r'ms	.....	142,000 cu. ft.	.....	"	C.		
Washington, D. C.	Chapin, Sax & Co.	Ice plant	.....	.....	.....	"	"		

already constructed of concrete. In addition to the buildings cited there are probably twice as many cold storage plants having concrete floors.

The writer of this paper extends his acknowledgments for valuable assistance in preparing the same to Mr. H. E. Plumer, C. E., contracting engineer, Turner Construction Co.; Mr. Junius H. Stone, manager of the Nonpareil Cork Works; Mr. John E. Starr, M. Am. Soc. Refrig. Eng.; Mr. Van Rensaeller H. Greene, chief engineer of the Manhattan Cold Storage plant; Jones Cold Storage Door Co.; U. S. Mineral Wool Co.; Union Fibre Co., and to a number of prominent reinforced concrete construction companies.

DISCUSSION.

Mr. Perry. MR. J. P. H. PERRY.—On the occasion of a recent visit to Pompeii something particularly interesting along the line of insulation came to my notice. In the Stabian Baths in Pompeii, which date from the Oscan period and are certainly in their present shape nineteen hundred years old,—Pompeii having been covered with ashes A. D. 73,—the caldarium or hot room is insulated in a manner quite similar to present practice in this country. The hot room is about 50 ft. long, 20 ft. wide, with a barrel arch ceiling. The construction consists of tufa block walls about 2 ft. thick. Against the inside of these walls were laid up terra cotta blocks about 1½ ins. thick and from 8 to 10 ins. square. Projecting from one side of these blocks is a knob about 2 ins. long. By means of these projections the blocks are kept at a distance of about 2 ins. from the outside wall, thus producing a dead air space. Next to this layer of terra cotta is a ¾ in. thickness of plaster, and against this is about a 2½ or 3 in. coat of finish plaster on which the mural decorations are painted. With this construction extending completely around the room,—that is, under the floor, up the walls, and over the ceiling,—there is obtained a remarkably good insulation—the thick exterior masonry wall, then the 2 in. air space followed by 1½ in. terra cotta and ¾ in. of plaster, and, lastly, in a separate course, the 2½ or 3 in. finish plaster. This latter thickness is laid up with about ¼ in. space between it and the ¾ in. rough plaster next to the terra cotta. It was particularly interesting to find that in Pompeii two thousand years ago the art of maintaining artificial temperatures was as well understood as the baths thus described would indicate.

EVOLUTION OF REINFORCEMENT FOR CONCRETE.

By Harry F. Porter.*

There are always three stages in the development of an industry. First, the pioneer stage—this is characterized by uncertainty, speculation and experimentation. The confidence born of exact knowledge and long experience is lacking, means and methods are crude and independable, and results follow only application of considerable nerve and persistence; hence construction is tedious, complicated, long-drawn-out, and therefore unduly costly. Progress is, in addition, retarded by ignorance, misrepresentation, ultra-conservation and prejudice. In the reinforced concrete industry this period occupied the last quarter of the nineteenth century, and may practically be considered to have terminated with the advent of the new century. Its leading spirits were men like Monier and Hennibeque abroad and Ransome in this country. They blazed the way. Attesting their efforts are many notable and enduring structures and devices and methods that together will constitute an everlasting monument.

Then comes the second stage in the development—the awakening! The demonstration has been made, and lo! in a night, almost, the intelligence sweeps like wild-fire over a country, leaving in its wake a wild, blind fervor of enthusiasm. It is on every tongue. Bold pilots of progress proclaim its mighty merits far and wide and prophesy in glowing terms its wonderful portent. Then genius camps on the trail, and behold! almost over night a multitude of mushroom ideas materialize—devices and appliances, systems and methods, without end, all intended and claiming to meet the needs of the infant of so much promise. Naturally enough, each and every scheme put forward is "the only one satisfactorily meeting the conditions, not to say the best and cheapest on the market." In the merry mêlée of exploitation

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of rival products that follows, fame, favor, and fortune run rampant, and reputations and solvency are wrecked on the shoals of inexperience. If such is the general experience, it is even more true of the cement industry in all its departments, for no industry in the history of the world has ever showed so extraordinary a development in so short a space of time. This second stage, too, is already on its last legs—let us give thanks! But we are all familiar, some of us to our sorrow, with its flashy, flimsy, fallacious features.

We come now to the third and final stage, in the evolution towards the ideal—when out of the medley of experience, experimentation, and analysis, there emerges saner, safer, and sounder *modi operandi*, like order out of chaos. This is the period of simplification, systemization, and standardization. Such was the history of structural steel construction, and such is morally certain to be the history of this newest building material. Indeed, already—so rapid has been the rate of change of men and methods in this modern age of miracles—we find the tide setting in strongly towards this final period all along the line. In every branch of the cement and allied or dependent industries, we find the balance swinging to a level—in the one pan are simplicity and system, in the other efficiency and economy. As in all matters in which the hand of the human meddles, first all is a jumble and a maze, then gradually, as the principles underlying begin to be discerned, the snarls are untangled, the rubbish cleared out, and the bubbles of speculation exploded.

Let us for a moment glance at what has taken place in reinforced concrete construction. Formerly, a concrete job resembled nothing so much as a "Tower of Babel" jumble—all was confusion and uproar by reason of the unskilled, unintelligent workers it was necessary to employ, because the very newness of the construction precluded the availability of skilled workmen. Few had the necessary courage to tackle, on any scale at all, reinforced concrete construction in those days. Little wonder conservatism looked on askance, and deep-seated prejudice was inrooted, which we are laboring now to remove and for which prime purpose organizations like the "National Association of Cement Users" came into existence.

To-day, partly as the fruit of this educational campaign and partly by natural order of progress towards better things, we find a far different state of affairs. Order is replacing confusion, and assurance suspicion—the young tree has weathered the fury of the elements and is waxing into stout, healthy maturity. Reinforced concrete is fast becoming known to the world as a safe, satisfactory, and economical material out of which to build our engineering structures, and, moreover, possessing points of merit that recommend it above and beyond any other material.

In this paper we will consider the development of one item only—the steel reinforcement, which is, however, relatively speaking, the backbone of the construction. Formerly, and in many localities to-day, in which ignorance still dominates, no attempt was made to insure accuracy in the placing of the reinforcement. All was left to the intelligence of the workman, a quality generally conspicuous by its absence. Result? Confused and tedious installation, general sloppiness, ruinous waste of time and materials, unsightly workmanship, excessive cost, and worst of all, dire calamities. A formidable array of charges against "loose-bar" installation, you say; but it is only the indictment of slovenly and haphazard wherever and whenever found. Specifications, to-day, that permit of these practices—"any old way good enough, so long as the theoretical amount of steel is provided"—are criminally negligent. Let me quote from a specification which is as it should be:

"All steel to be of best quality made from original billets and in strict accordance with the regulation standard for structural steel. It shall be free from all scale and laminations and defects endangering the strength of the material. It shall also be free from all dirt, oil, and rust pocks, although a slight film of rust is permissible. The ultimate strength shall not be less than four times the safe unit stress used, and the elastic limit less than two and a half times.

"All reinforcement to be properly fabricated and supported in position, so that all parts shall remain in true relation and alignment until locked in the setting concrete.

"All tensile stresses, theoretical and practical, that may occur in the structure and any of its parts shall be fully and properly

provided for by steel reinforcement. In general the reinforcement shall run as continuously as possible throughout the structure, and full development of every piece provided by suitable end-anchorage and lapping.

"Diagonal tension in beams to be cared for completely by diagonal reinforcement, either a part of or rigidly attached to the main reinforcement. In the slabs, these stresses and the negative stresses shall be cared for, simultaneously with the positive stresses, by elevating a sufficient number of the bars across the supports, providing in effect a catenary curve reinforcement.

"Vertical tension to be cared for by vertical loops of steel, passing around the lower horizontal bars and extending well up into the compression flange in which they shall be well anchored. These loops or stirrups shall be spaced not farther apart than the effective depth of the member and at progressively diminishing intervals towards the supports. In case of T-beams vertical stirrups are necessary to guard against possible separation of the rib from the slab along the plane of junction and to insure the full and proper development of the T-action.

"All placing of reinforcement shall be done before undertaking to concrete, so that in amount and position it may be easily and fully checked before any concrete is deposited; conversely, no steel shall be left to be placed while the concreting is in progress.

"In slabs and walls, if bars be used, cross or shrinkage bars shall be provided at proper intervals, the intersections securely wired or clamped, and the bars properly and securely spaced and supported in position, prior to any concreting," etc.

This is almost the exact counterpart in letter, and identical in spirit, of a specification from which a large number of important structures have been erected in and around Philadelphia, and in Toronto, Canada. It should be apparent to all that they are couched in no mistaken or mistakable terms—they were written to exclude the use of the criminal "loose-bar" methods, or rather un-methods, and to compel the use of a superior unit frame fabrication, either field or shop assembled.

In considering the evolution of concrete reinforcement, we have a two-edged guide—efficiency and economy. When these

walk hand in hand, then we have the ideal. We have satisfied the criterion, "the best for the least money."

There have been many frames on the market which have been efficient, so far as taking care of the stresses theoretically and practically is concerned, but all have had a hard struggle for existence because of their excessive cost. In the run of competition—the survival of the fittest—they have one after another fallen by the wayside. To really master the situation, it has seemed necessary to provide a unit frame at no greater cost than the far less efficient "loose-bar" methods. This is an error of judgment which only experience can correct. Judged by the bound-to-be incomplete and faulty cost keeping records of "loose-bar" installations, unit frames will never equal this requirement. Weighed in the balance with the value in dollars and cents of greater accuracy, greater confidence, and greater speed of construction, not to mention the saving possible by the leeway in calculation afforded and the reduction in inspection necessary, unit frames are even now more economical. This fact will ultimately lead to the universal adoption of unit frames, either shop or field fabricated. It will be a happy day indeed, for those who have the highest good of the industry at heart, when "loose-bar" methods are forever a thing of the past.

Under the heading "unit frames," there are ordinarily three general types—field fabricated, shop fabricated, and "trussed" bars. Let us consider their respective qualities in the order named. Field built frames are, as the name signifies assembled at the site of the work, the raw materials coming direct from the mill, and all bending, trussing, wiring and fabricating being done right on the spot. If the work be carefully executed—bends correctly made and wiring properly done—and proper means are taken to maintain the reinforcement in correct position, the field-fabricated method may be very successful; but from the very nature of things, it is a tedious, unscientific and expensive mode of procedure. It cannot claim to be "efficient" in the full and proper sense of the word, and is at the best only a makeshift. It involves too great a waste of time and money on preliminary and minor details, and introduces too many chances for error of both carelessness and ignorance, to withstand final elimination.

Secondly—the "Shop-built Unit Frame," in its original form, is now obsolete, although in modified and improved form it is still on the market. It died a natural death—not because it did not fulfil the requirements of safety, but because it was alike too cumbersome and costly. There were other objections—more incidental and trivial than vital. It was good but not good enough. To those who are not familiar with this type of frame, I will explain that it was built on the same lines as the field-built systems, but all mechanical work and assembling was done in the factory; wiring was likewise eliminated, all affixing being accomplished by use of metal clamps. The frame went to the job a complete unit ready for placing. A vital disadvantage of this and all similar frames is the space required in shipping, with consequential undue expense for transportation and handling in all the operations preliminary to final disposition. Another disadvantage is the difficulty and expense of altering or remedying mistakes after the frames have once left the factory.

We come now to the third general type—that combining the minor reinforcing members to the main members in the process of manufacture, either by rigid attachment through the natural fibres of the material or by mechanical clamping or by electric welding. This type has met with a wide usage and is still a favorite in many quarters. For many purposes—such as isolated, rectangular sections freely supported—it is almost ideal; but it is not and cannot be a sovereign panacea for all the troubles of the reinforced concrete constructor. Especially in building construction, where practically all beams are T-sections, and it becomes very necessary to have a positive metal bond between the rib and the superimposed slab that forms an integral part of the member, such reinforcement is of itself inadequate. It is then good practice, if not an absolute essential, to have through the medium of vertical stirrups a positive tie between the horizontal reinforcement below and the slab reinforcement above. If installation were in every instance to be monolithic—that is, if soffit and slab were to be always poured in immediate sequence—it would perhaps not be so essential. But the reverse is the rule, so that it does become for practical reasons indispensable. It is mostly for this reason that the building codes of many of our

municipalities, particularly Philadelphia, require the presence of vertical stirrups the entire length of the beam, spaced not further apart than the effective depth of the member. No type of reinforcement dependent for the development of the proper action, that is, the correct distribution of stresses, on the inconsequential grip of a thin fin of steel in a few square inches of compression concrete, can without availing itself of auxiliary devices that mean extra expense, satisfy this condition. Moreover, in the simplest cases, this type of reinforcement cannot in cost compete with field fabricated methods, involving no special, patented sections.

What I wish especially to place before you for your enlightenment and consideration, because it has grown partly out of the writer's individual experience and he is therefore well posted to tell about it, is another type of unit frame, which is, roughly speaking, a cross between the first two types. In other words, it is partly shop and partly field fabrication. It is a system devised to fulfil the requirements of the kind of specification afore quoted most economically. As the outgrowth of practical experience whose guiding star was the two-fold ideal of efficiency and economy, it embodies the simplest principles and is adapted to the widest range of choice in materials. Thus, it may be confined to plain bars alone; it may be confined to deformed bars; it may use both kinds in combination; and finally either or both may be used in combination with a mesh for slab reinforcement. Its gauge is thus broad and generous enough to take care of all conditions and tastes. It has in the past year and a half entered into the construction of upwards of fifty structures of note, aggregating in value over $10,000,000.

This unit is shop built in so far as all mechanical work necessary is done in the factory. It is a field-built system in the respect that the actual assembling into a frame is done right on the job —indeed right in the molds, so that the material is kept in simplest possible form for ready and economical handling until the very last moment. No attempt is made to fabricate the heavy and light elements of the reinforcement into an unwieldy cage in the factory. The stirrups alone are fabricated into a frame of itself. This stirrup frame, on account of the pivotal action allowed by a special form of spring wire clamp employed in attaching each

stirrup to a longitudinal or frame bar at each bend of the stirrup, may be collapsed for ready and compact handling from the instant it leaves the factory until it is desired to place it in its final resting place. It is then pulled into upright position again, regaining its original form exactly, and dropped into the molds. The upper ends of all stirrups being formed into a hook of special design, the whole frame comes to rest in the mold in exactly the proper position, constituting a saddle in which the main reinforcement is placed and maintained in position. Little metal separators are employed in addition to hold the bars in proper position relative to one another and the stirrups.

As to the use of the "frame bars"—which make the frame a possibility—the upper pair, catching on the under side of the

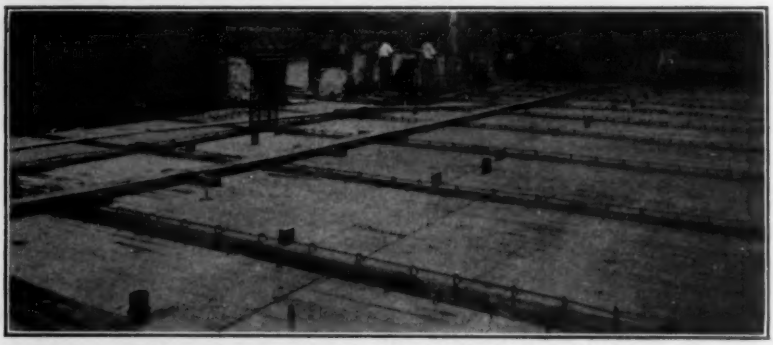


FIG. I.—BEAM REINFORCEMENT READY FOR CONCRETING.

hook of the stirrups, forms in effect anchors to increase and distribute the grip of the stirrups in the compression flange, thus materially stiffening the beam. They also serve as shrinkage bars for the slab, and, to many engineers who deem the presence of some steel necessary in the upper fibres, a useful part of the reinforcing system. Furthermore, they serve the additional and very useful purpose of providing support for the slab bars as they cross the beams, compelling them to assume to all practical purposes a catenary curve. This fulfils another requirement of the specifications before quoted. By occasionally—every three or four bars—passing a bar underneath the frame bars a further enhancement of the tie between the rib and slab is had. The lower pair of frame bars, in addition to spacing and holding the

stirrups at the bottom, as the upper frame bars do at the top, serve as fireproofing bars to the main steel, from which they are separated by the thickness of the stirrup stock. Obviously, in a severe enough fire to spall the concrete on the under face of the beam these would interrupt the checking to a large extent, performing a function similar to that of the bars on the under side of a fireproof steel beam. Moreover, their tensile strength may

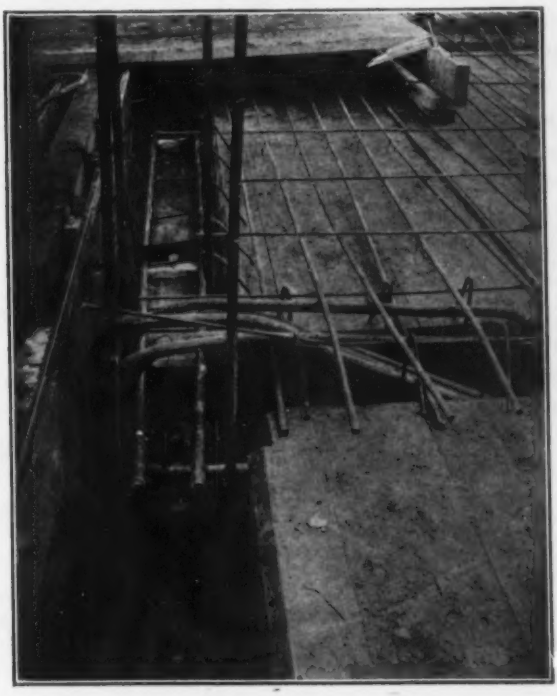


FIG. 2.—INTERSECTION OF COLUMN, GIRDER AND BEAM REINFORCEMENT.

be utilized if needed. Ordinarily inconsequent for this purpose because of their small diameter—¼ inch or 5/16 inch—by using a larger section an addition to the workable tensile area may be realized which affords a very convenient margin of adjustment.

There is thus practically no excess material used, nor any wiring with its expensive hand-labor required. By the use of a few simple spring wire clips, inexpensive alike for the making and for the attaching, the whole thing is made possible while

adding but a fraction to the total cost based on the total tonnage. All mechanical work being performed in the factory where the well known economies of factory production may be realized, the cost is less than for any field-built methods of perhaps equal efficiency. All cutting of material for stirrups being made from coils, the waste item incident to field making of the stirrups is eliminated, and all bending of same being done by automatic machines, another important saving is realized over field making. Mistakes may be easily rectified in the field. Inspection is easy. Installation is both easy, rapid and cheap, and last but not least a very superior construction all around results, which under the requirements of the present building laws, develops extraordinary efficiency. The same principle is applied to column reinforcement, both rectangular and spiral, with equally good results, and by the use of similar spring wire clips and spring wire stool lock spacers the problem of spacing and supporting the slab and wall reinforcement is as simply, efficiently and economically met. In the writer's experience he has found this system cheaper than loose-bars and infinitely more satisfactory.

A comparison of costs for loose bar and unit system installation is as follows:

ANALYSIS OF COST OF LOOSE-BAR INSTALLATION
BUILDING CONSTRUCTION.

Base at mill	per ton	$30.00	
Freight from mill to siding	"	2.00	
Hauling to site of work	"	1.00 to	$2.00
Allowance for sizes below base	"	1.00 to	2.00
Cost f. o. b. job		$34.00 to	$36.00
Racking		1.00	
Bending Hooking		2.00 to	5.00
		$37.00 to	$41.00
Hoisting		1.00	
Placing		5.00 to	10.00
Total cost in place		$43.00 to	$51.00
Allowance for waste		.50 to	1.00
Final total cost in place		$43.50 to	$52.00
Cost f. o. b. job		34.00 to	36.00
Cost of installation, per ton		$9.50 to	$16.00 Average $12.75

To this must be added an amount to compensate for the increased cost of the total operation due to the delay and confusion incident to every loose-bar installation. For example, the cost of placing the concrete alone may easly be increased 100 per cent. by the interference had. In order to place concrete efficiently and economically, it is necessary to have the fullest and freest hand possible once the operation is begun. This is only possible when all steel is in correct position and provision made to maintain it there during the succeeding operations before undertaking to concrete. With a loose-bar or semi-loose-bar installation, this is never possible. In case reinforcement is placed beforehand and well supported and wired, we have in effect a unit reinforcement which allows us to concrete to fullest advantage. Cost of such supporting and wiring, if thoroughly done, will average $5 per ton. The total charge for steel in place, above cost delivered on job, will then average between $15 and $20 per ton.

Contrast these figures and facts with those of a unit installation.

ANALYSIS OF COST FOR UNIT FRAME INSTALLATION.

Base at mill ..... per ton	$30.00	
Freight ..... "	2.00	
Hauling to site ..... "	1.00 to	$2.00
F. o. b. job	$33.00 to	$34.00
Total cost of fabricating metal (includes assembling of stirrup frame, trussing of bars, and all accessories)...	5.00 to	8.00
Ready to place on work.....	$38.00 to	$42.00
Handling charges, receipt on job until ready to place in molds (includes racking and hoisting).....	$1.00 to	$2.00
Placing in molds	1.00 to	2.00
Brought forward	38.00 to	42.00
Total cost in place	$40.00 to	$46.00
Average price per ton in place, for base of $30.00.....	$43.00	
F. o. b. net (average)	33.50	
Cost of installation per ton.....	$9.50	(Average)
Total cost above base, average per ton.....	13.00	

It will be observed that in this case the cost for unit system that fulfils all the requirements of efficiency, is less than the cost of a loose-bar installation. Weighed in the balance with reduced cost of total operation due to facility and speed of operation made possible it is far cheaper. Consider the reduction in all sizes possible by reason of the greater accuracy guaranteed and the advantage is still greater. Engineers aware of the inaccuracy of loose-bar methods allow, or should, a very material factor of carelessness when these are to be used. Assured of careful, accurate installation—as is the assurance with a unit fabrication—they may very well reduce the total cost, by closer calculation, from 10 to 20 per cent. While they do not at present, the building regulations are bound in due course to recognize this superiority by a suitable allowance in favor of unit systems.

CONCRETE APPLIED TO DWELLING HOUSE CONSTRUCTION.

By Ross F. Tucker,* M. Am. Soc. C. E.

The next step in the extension of the use of concrete will be its adaptation to the construction of dwellings. With the army of block machines that are on the market and the great quantity of output from these machines, the bulk of which goes into dwellings, the step above-mentioned has already been in a manner taken, although in the writer's opinion, the technique of the method of manufacture to which many block makers are restricted, renders it difficult to manufacture a wholly satisfactory product. The percentage of water used in mixing will not sufficiently lubricate the aggregates to produce the greatest possible density and strength. All the ramming and tamping in the world, all the pressure that can be exerted by hydraulics or otherwise will not compress a dry, poorly-made concrete into a dense, water-tight block. The particles of aggregate arch themselves and cannot be forced to fill the corners and interstices without sufficient water to allow the faces and surfaces of the aggregate to slip on one another.

It is curious that so many people have taken to block-making as if there were something new about it. Artificial stone was made thirty years ago, and in a manner similar to the block machine method of to-day, and the resultant product had many of the defects of these later productions—a soft, absorbent, spongy mass, of low compressing strength, requiring all sorts of treatments to make it waterproof. The whole practice is wrong, and the only difference between the old method and that of to-day lies in the numerous mechanical devices, which, with greater or less ingenuity, reduce the labor and mold cost to a minimum. All walls built of such material must be so constructed as to avoid the dampness that such concrete must neces-

* President, Concrete Association of America, New York, N. Y

sarily acquire, and the very softness of the stone precludes any surface treatment that can be called interesting or satisfying in any degree.

All concrete, to be strong and sound, must be wet concrete, far too wet to be delivered from its mold for considerable periods of time. The best artificial stone made in this country to-day is manufactured in Boston by the wet process. The selection of aggregates, together with intelligent mixing, secures results that in the finished product, are astonishing and are not attained by any process block machine yet devised.

Again, solid wall construction is very limited in its application to dwelling house work. While we have about solved the problem of the mill and factory building, both structurally and economically in reinforced concrete, the same cannot be said at all of dwelling houses. In the mill and factory structure we have a relatively large amount of concrete as compared with the lumber and labor involved in the making of the forms, whereas, in the dwelling house, with the cut-up surfaces and irregular openings, the ratio of the cost of forms to the concrete is out of all proportion and places concrete practically out of the running in comparison with other material. Moreover, the internal stresses, particularly the shrinkage of concrete in mass, are such that the walls are almost sure to crack. They must be furred or an air space formed, otherwise they will be damp and extremely unsatisfactory. In the fall and spring there is a likelihood of condensation on the inside of an uninsulated concrete wall, and, last of all, it is a difficult matter to give a solid wall any architectural treatment that can be called satisfactory, except at a very considerable expense.

The wooden house is, of course, highly inflammable and should be only built as a last resort. Such a house covered with metal lath and furred has some excellent architectural possibilities, but when well-built, will not be found to be cheaper than a rough brick wall, for the frame must be sheathed, papered, metal furred and lathed and covered with scratch coat of mortar before it is in condition to receive the stucco. This will be found to approximate closely the cost of brick work. Much has been said about the faults of stucco work, but like many

another failure in the use of concrete, they are traceable to the ignorance of the user rather than to the fault of the material. Stucco has been greatly abused but it will do good service every time if properly made and applied. I have placed ornamental stucco on the exterior of a power house on the St. Lawrence River, on tile, brick and lath surfaces where it has been subjected to a yearly range of 120 degree temperature for ten years, and it is as good to-day as when applied, although the plastering on the inside, made exactly the same way, of the same material, came off in pieces a yard square on the same walls within two months after it was applied.

Stucco should be made of selected material, not of dirty, clayey bank sand. There are great possibilities in the future of stucco when properly handled. But for this development must come a cheap wall. The writer had occasion to make a study of this problem of a cheap wall construction for stucco application for the late Stanford White, who, had he lived, would have taken some steps to show what could be done in decorative stucco. But all existing methods have been too expensive and we must devise a cheap dry wall before we can make material progress in dwelling house work. The terra cotta wall is a relatively cheap wall, but its lack of fire-resisting qualities, its tremendous expansion under heat, make it a dangerous wall, unless insulated and protected. The nearest approach to the ideal wall for concrete dwelling houses seems to have been worked out through the method of placing wet concrete into steam jacketed molds and rapidly hardening it by a controllable heat. This method has proven economical and seems to have solved the problem of handling wet concrete and producing a dense, strong building unit at a very low cost. Considerable building has already been done with these blocks, and the development will be watched with great interest. With such a wall, the extension and possibilities of concrete decoration are unlimited and the future will give us fireproof homes of high structural and architectural value at low cost. The method is so simple, the requirements of skilled labor are so greatly reduced, that houses of concrete, fireproof throughout, may be constructed at a price to compare favorably with wood, and upon the walls

may be produced a great variety of color and texture effects, in stuccos made of many materials, enlivened with masses of color in Faience and Mosaic, that give the architect great opportunity for the exercise of his artistic abilities. It will create a school of design adapted to the material and be productive of a style of dwelling possessing individuality and character combined with durability and permanency such as we know little of thus far in our suburban architecture.

WATERPROOFING—VARIOUS APPLICATIONS AND COMPARATIVE COSTS.

By T. Hugh Boorman.*

In 1874 I imported of J. B. White & Brothers, 400 barrels of Portland cement and considered it a big consignment, and the same year laid for the City of Boston a few hundred feet of sidewalk, which my partner, Mr. Henry Taylor, of London, christened "Hydrolithic" pavement. Who in those days could have foreseen the tremendous industries which would be evolved through the use of Portland cement? The business now is colossal, employing outside the factories, thousands of skilled artisans, hundreds of able civil engineers and rendering possible the erection of buildings and structures which our fast diminishing supply of timber could not be depended upon to furnish to an adequate degree. Single buildings are now erected at a cost which would a quarter of a century ago have built a fair-sized city. This century has, indeed, been ushered in by improvements in construction beyond the wildest dreams of my youth, and with this great volume of work has arisen the call for specialists in all lines of construction.

Let us consider the possible damage sustained through mistakes in rendering buildings waterproof; fire annihilates millions of dollars of property annually, a dead loss to the community which can never be replaced; how much material is annually ruined by water and dampness? Also an irreparable loss. It is as necessary to protect a building at the foundation from water as at the roof, therefore the question of waterproofing cannot be too thoroughly considered.

I will call attention to various methods and applications of material and would like such free and open discussion as may tend to enlighten us as to possible improvements on a question of which there is yet much to be learned. I am in most hearty

*Civic Engineer, Philadelphia, Pa.

sympathy with the statement made by Mr. Myron H. Lewis, in his address on waterproofing read before the Engineers' Club of Philadelphia, June 6, 1908, that architects and engineers have often false impressions as to the immunity of structures from water penetration, and with a view of keeping down the cost, have chosen to look upon the important item of waterproofing as a superfluity.

Unfortunately, those engaged in the waterproofing business are usually practical men, with but little desire to give to the public the benefit of their experience, and the narrow policy hitherto followed by a large proportion of them has been not only narrow but obstructional in its results. Narrow, because each concern has arrogated to itself a monopoly of the only successful methods of waterproofing known, and not even content with this, they have taken the untenable position of disparaging and even denouncing as worthless the methods and materials of their competitors. Narrow also, because some of them have put forward their own materials and methods as infallible cures for all possible conditions, and make other extravagant and impossible claims, which instead of inspiring confidence and attracting support are rather calculated to awaken suspicion and distrust in the mind of the intelligent and critical purchaser. We have long been accustomed to see printed in public advertisements that this or that compound is the only permanent and efficient waterproofing material known. And we have seen this statement so often that skepticism has developed into downright unbelief. We all of us realize that no individual firm enjoys a monopoly of the materials which nature has supplied us with; and that to such a firm only is given the power to produce a material that is permanent and efficient. In my opinion, such a policy could only react upon the industry in general, by causing a loss of confidence in the entire scheme, and as a consequence, bring confusion and loss upon the people who had hoped to benefit by it.

I shall define existing waterproofing methods under three heads,—Hot, Cold and Dry. The *first* applies to all methods embracing the use of asphalts and pitch, which have to be heated on the work. The *second* system in which liquid or plastic materials are applied without heating, and the *third* to the system

of mixing material with the cement to make the same waterproof in its various uses.

HOT METHOD.

Bituminous waterproofing, that is, combinations of asphalt and pitch with felt burlap and duck are used with the greatest variations in the materials, from the high-grade asphalt to the cheap coal tar pitch. The widest known method of waterproofing masonry and concrete has been the application of some form of bitumen. There are a number of difficulties encountered in this method, owing to the physical properties of the bitumen used, which could be summarized as follows:

1. If the waterproofing layer is made from a hard asphalt fluxed back to proper consistency with an oil, the oil is gradually absorbed by the concrete and the bitumen becomes hard and crumbles.

2. If the waterproofing is made by dissolving the bitumen in a volatile solvent with a dryer, so that it may be applied cold like a paint, it is difficult, if not impossible, to prepare a paint of this character that will dry to the right consistency and then stop. The usual result is that the drying or hardening continues until it reaches a point where it is destroyed by its own contracting and the waterproofing is gone.

3. Another difficulty is that the bituminous matter used, such as coal tar pitch, is so susceptible to variations of temperature that in warm weather it has a tendency to flow, and in cold weather it becomes hard and very brittle; either condition being fatal to successful waterproofing.

To meet these and other difficulties a tough asphalt product of refined petroleum has been introduced in many specifications. It contains no oil or flux but is homogeneous throughout. The fact that it is maintained at a temperature of 500 degrees F. for several days in the process of manufacture is sufficient assurance that it contains no volatile matter. It will withstand the widest range of temperature conditions. At 0 degrees F. it is tough and pliable and shows no tendency to crack, while at 150 degrees it is still tough and firm. It does not flow under 250 degrees F.

Such asphalt is not affected by acids or chemicals and will not deteriorate. This is determined by coating glass with a thin film of the material, and submitting the coated glass to such conditions or chemicals as might cause deterioration, and after several months the film of asphalt is scraped off, made into a block and tested to see if deterioration has taken place.

As to the practical application of this asphalt where the surface to be waterproofed is smooth and free from voids, the material, after first being melted, can be swabbed on like a paint, four coats giving a layer about one-quarter of an inch thick.

The asphalt may be applied in this way with alternate layers of asphalt and felt. In this case there should be at least one-quarter inch layer of felt so that in case of rupture to the waterproofing coat, there may be sufficient material in each layer to press across the rupture and enable the waterproofing to be self-healing. Where the surface to be waterproofed is rough the first layer of asphalt should be applied by placing wooden forms at the proper distance and filling the forms with the melted asphalt. The forms should be lined with paper to prevent the asphalt from sticking. After the material has cooled, the forms may be removed and used again. In this way the asphalt penetrates all the voids in the wall and is not in danger of being ruptured by pressure. After this is done asphalt may be applied, or alternate layers of asphalt and felt, until the desired thickness of the waterproofing coat is reached.

Owing to the rubbery nature of such asphalt when used in joints of concrete work it not only renders them waterproof but compensates for the contraction and expansion of the concrete. It has been very successfully used in this way in government fortifications and in the dry docks at the Philadelphia Navy Yard, also in the large filter beds of the City of Reading, Pa.

The specifications for waterproofing of the bridges in the District of Columbia, prepared by the Engineers of the Baltimore and Ohio R. R. in connection with the Engineers of the Pennsylvania R. R. and the Engineers of the District of Columbia, read generally about as follows:

After the concrete surface has been thoroughly cleaned of all dust and debris, it should be painted with a soft tar, heated to a fluid condition, and immediately covered with a layer of medium weight water-

proofing felt. The felt should be applied to the tar while hot, to insure its adhesion and should be beaten with heavy wooden spatules to press it completely to and into the tar coat. In laying the felt, all joints, ends and laps should be painted with hot tar for a distance of 4 ins. back from the edges and the succeeding and adjoining layer should lap not less than 4 ins. over and onto the previously laid material.

After the felt is laid it should be immediately swabbed all over with a coat of hot tar, care being taken at the joints in the felt to see that they are perfectly sealed. When this work is completed the principal body of waterproofing should be applied. This should be pure asphalt with petroleum base.

The asphalt having a penetration on Dow's machine of 69 D C standard at a temperature of 77 degrees F. or of the softness of the material used on the work of the Baltimore and Ohio R. R., should be heated to a temperature of between 300 and 350 deg. F. in kettles designed for the purpose located as close to the work as practicable in order to retain as much heat in transporting in buckets as possible. This heat should be derived from cord wood, and while heating the asphalt should be constantly agitated or stirred to prevent cooking or scorching.

When the asphalt has been heated to proper condition of fluidity, it should be drawn from the heating kettle into buckets for transporting it to the place of final deposit in the work.

In order to prevent the asphalt from flowing over a greater area than it is possible to completely cover to the required thickness in a single pouring from the kettles, a bulk-head or confining strip of dressed wood 2 by 4 in. in section, long enough to permit wedging at the girders, should be placed and coated with plastic clay, to prevent the asphalt from sticking to the wood. This strip should be tightly wedged, it being remembered that, when hot, asphalt has the characteristics of a heavy fluid. In joining a new bed to one already made and hardened by temperature reduction, care should be taken to see that every particle of clay or other foreign matter is removed, and that the joint is solid and firm, so that good adhesion can be had at the surface of contact.

If the transmission of heat from the newly poured material at the joints is insufficient to make adhesion to the cold surface perfect, a heavy hot asphalt smoothing tool should be skillfully passed over about four inches of the upper surface, adjacent to the joint, heating the materials until they become plastic, and the joint is perfectly sealed. The asphalt should be laid in two layers. The first one, as described above, should be about one-quarter inch in depth, and covered when hot with No. 33 silver finish wire mesh 12 x 12 to the square inch, care being taken to lap well at joints.

The second course of asphalt should be prepared and applied as described in the first course, poured in confined areas, to a depth of 3/8 in., and while hot covered with a layer of heavy, openly woven canvas or

burlap, the asphalt being forced through the weavings in the material by pressing the canvas into the hot asphalt and the canvas should be painted with a heavy swab coat of asphalt—this coat should cover every part of the canvas and close every joint and opening. In all this work, care should be taken in every operation to get perfect adhesion and close sealed joints. The waterproofing layer is now about 0.90 in. in thickness over the floor generally, but at the sides adjoining the girders, etc., the asphalt should have an increased thickness of about 1½ ins. at contact points and for a distance of 4 ins. away from it. This can be accomplished by the use of 2x4 in. pine strips, heretofore mentioned, properly placed and braced.

Before pouring this material, however, the steel at contact joint should be freed from paint, oil, grease, etc., so that the asphalt will stick; also, just before pouring, the steel should be heated with a gasoline torch, and as this joint is one of the most important in the work, too much care cannot be taken to insure perfect work.

I recently noticed a piece of waterproofing in connection with the track elevation, Philadelphia and Reading Railway in the City of Philadelphia, that was especially interesting to me, and no doubt, it will prove equally so to any railway engineer.

The bridge floors are of the trough type, the depth of the trough varying according to the span—6, 12 and 24 ins. The method consists, first, in grading the trough from either end to a central point by means of 1-3-6 concrete. At the same time a concrete flashing is placed against the sides of the steel girders extending up to the base of rail. After the concrete had been dry the entire surface of the concrete, as well as all exposed steel below base of rail, was painted with a concrete filler (pure asphalt reduced to the consistency of paint); the above work all being preliminary to the waterproofing proper, which consists of European Rock Asphalt, American Pure Bitumen 220 degrees melting point and mineral aggregate. The exact proportions of the mixture* I am not able to give you at this time. The bottoms, sides and tops of the troughs were completely covered with the waterproofing, as above described, the thickness on the

* NOTE.—Mr. Samuel Tobias Wagner, Assistant Engineer, Philadelphia and Reading Railway, supplies the following additional information:

The concrete floor covering consisted of pure asphalt reduced to the consistency of paint by means of 62 Baumé naphtha. The proportions of the rock asphalt mastic are as follows.

Imported Rock Asphalt, 60 parts; Refined Asphalt, 10 parts; clean, sharp grit and sand to pass sieve of 8 meshes, 30 parts.—ED.

sides and top of trough being 1½ ins., and the bottom of the trough 1 in. The trough has a 1½ in. drain pipe in the center which empties into a U-shaped steel gutter supported from the under side of the bridge floor. The water is taken from the gutter by means of downspouts at the columns. The general appearance of the work is creditable, and I have been informed that the results, so far, are highly satisfactory.

COLD METHOD.

The cold process or application of cold asphalt materials covers the use of four distinct manufactured articles.

1. Material for protecting interior walls from dampness.

These are impervious compounds in which water resisting agents are scientifically combined; these are so prepared as to interpose a firm bond between the plaster and the inner face of brick or stone walls, over which the compound makes an impenetrable film, continuous from cellar floor to roof beams. It, therefore, intercepts all dampness from the outer walls. It prevents moisture from penetrating the outer walls to the plaster, and thus preserves the latter from damp stains. It serves every purpose for which furring and lathing are used. It makes an inseparable bond between the plaster and the brick or stone wall to which it is applied.

With such a dampproof coating there is no further need of furring, which while designed as an insulating medium, becomes in time a source whence germs are developed, a harbor for vermin and not infrequently a hiding place for smouldering fires.

It checks the exudation of salts in fireproof tiled walls which would otherwise discolor the plaster.

2. A colorless compound which seals the surface of the outer wall against water and atmospheric moisture, and can be applied to the finest stone and fronts without marring the architectural effects of color in the building.

Driving rains and atmospheric moisture if allowed to expend themselves upon exterior masonry walls, stone, brick or concrete and mortar, must suffer in a way to seriously affect the durability of the building. Even though the inner walls be secured

from dampness by a waterproof coating, the unrestrained action of rainstorms and atmospheric moisture on the outer walls will hasten decay of the masonry, although the inner walls may themselves remain dry. The salts in the masonry, stimulated into action by dampness, exude and burst out in the disfigurement known as efflorescence, which is not only unsightly, but destructive, since efflorescence in itself, becomes in time a generator of dampness.

It prevents the exudation of salts in the masonry, thereby checking efflorescence. It is not a surface coating, such as might of itself be at the mercy of the elements. It is a liquid, penetrating in character, and entering the pores of the masonry, it impregnates and fills it with an indestructible substance, to the absolute exclusion of moisture. It is colorless, so that the exterior surface of the building gives no evidence of its appearance.

Among its various uses are protecting parapet walls from rainstorms; waterproofing swimming pools, silos and underwriters' tanks, and making leaky walls watertight.

3. The stain-proofing compound, for stain-proofing marble, granite and limestone. To preserve the original delicacy of coloring in light-colored stones, one of the first and most necessary precautions to be taken is to exclude all dampness from the stone. This can only be done by the application of a compound which effectually closes the pores and prevents the percolation of dampness or moisture through the no molecules of the granite, marble or other stone.

It takes the place of the so-called non-staining cements which are not always stainless. It has all the properties required for this purpose, and can be safely substituted for the so-called non-staining cements. Besides its greater efficacy in preventing the discoloration of the stone because of its resistance to dampness, it also counteracts the injurious influences of chemical action from the surrounding masonry.

4. The heavy asphalt cold compound for damp-proofing substructures. This has all the properties requisite for providing a watertight foundation. In many features it is bituminous, plastic and elastic. It is used either alone or in conjunction with felt saturated with asphalt, or with burlap, and is applied to underground masonry, vault arches, etc.

Applied cold instead of hot, it does not set instantly, therefore much easier to apply than hot pitch. The work can be done by an ordinary laborer, care rather than skill being required in its handling. All walls that are to be waterproofed must first be made dry, and if concrete walls, they must have been allowed to thoroughly set. It preserves the original strength of the foundation wall by maintaining them dry.

DRY METHOD.

Dry waterproofing is the method of adding a waterproof compound to the hydraulic cement mixture. Concrete has a tendency to "soak." The question of eliminating this defect is a matter of selection. The integral method has these points in its favor: simplicity in method, economy in price, certainty in results. A simple, effective and economical compound for obtaining a dry concrete is to add a waterproof compound to the mixture. This method will be found exceedingly adaptable when the purpose is either to waterproof the concrete throughout, or to provide a cement mortar which will serve as a waterproof facing. The high degree of efficiency to which a waterproofing compound of this character can be brought when developed on scientific, which really means practical, lines is exemplified in such compounds.

The dry method accomplishes the waterproofing of cement mortar and concrete by acting chemically upon the constituents of the body into which it enters. By this chemical activity it becomes an integral part of the mass, and the water-resisting property it infuses thereinto is not merely for a time, but it lasts as long as the material into which it enters. The compounds will neither affect the strength of the concrete nor its final setting. The uses to which it may be put in construction work are many. The following suggestions as to treatment under various conditions will bring the best results.

Reinforced Concrete: Where concrete is improperly made there may be produced a porous concrete of poor quality and a number of methods have been proposed to improve the condition of the concrete; among others, the use of dry waterproof compounds for incorporation in a sand mortar, which is applied as a coating to the exposed surface of the concrete.

Stucco: In this form of construction metal lath is used as a base and where concrete is improperly applied there is a possible danger of corrosion through moisture which may find its way to the imbedded steel. The use of a waterproofing compound for the exterior plastering is resorted to as a means of excluding dampness and also to improve the appearance of the wall by preventing the soaked surface which sometimes follows in the wake of a rain storm.

Sub-Structural Work: The waterproofing of the sub-structural walls of a building is a matter that is commanding a great deal of attention, and among the many methods the writer believes the plastering of walls with a cement mortar in which has been incorporated a dry waterproofing compound, is by far the best. Such a coating should be applied to the inside of the walls before the floor is laid, so that it will extend below the level of the floor line. The floor itself should be a supplemental layer of waterproof mortar.

Cement floors are usually laid in two parts: the lower, a stone or cinder concrete to serve as a foundation, the upper bed is composed of cement and sand, troweled to a smooth finish. To obtain a watertight floor, it is only necessary to add the waterproofing compound to the cement used.

Comparative Advantages: As compared with other methods of waterproofing structural work, the integral method has these points in its favor: *first,* its simplicity; it requires no excavation or sheet piling, as the waterproof course is installed on the inside instead of the outside of the walls. *Second,* its convenience; the walls can be waterproofed during one operation applied to one slab after the walls are erected, no necessity of waiting for masons or of making connections with a hidden damp course. *Third,* its accessibility, with the waterproof course on the inside of the wall, in the event of a leak, the latter can be readily repaired.

Artificial Stone: Cement blocks, as they are usually called, can be waterproofed throughout, if so desired, or they may be merely faced with mortar which has been waterproofed with these compounds.

Reservoirs, etc.: Concrete structures designed for retaining water can be made proof against leakage or inflow, by a coating

of cement mortar with which a compound has been mixed. The method previously prescribed for the treatment of sides and floors of sub-structures will be applicable to this purpose. In this class are included tanks, swimming pools, silos and the like.

General Directions for Using Dry Compounds: The waterproofing of concrete or cement mortar with a compound is a simple matter, as the following directions will show:

1. Add compound to dry Portland cement.
2. Mix these two materials thoroughly.
3. Add damp sand, using the desired proportions and again mix.
4. Add the quantity of water required for the mixture.

In making a waterproof mortar for facing walls of substructures, reservoirs, swimming pools, concrete water containers of every description, reinforced concrete, concrete blocks, stuccoed fronts, the quantity of compound used is generally about 2 per cent. of the Portland cement used. For waterproofing concrete blocks when compound is to be used incorporated in the mixture, from 1 to 1½ per cent. is generally used.

Covering Capacity and Cost: The average conditions require that the quantity of compound should equal 2 per cent. of the Portland cement, or 8 lbs. compound to each bbl. of the cement. At the rate of 12 cts. per lb. the cost, therefore, of waterproofing one bbl. of Portland cement with compound would be be 96 cts. The areas which one bbl. of Portland cement in various mixtures will cover, and also the cost of waterproofing cement mortar per 100 sq. ft. are set forth in the following table:

Proportions.	Thickness of Coating. Inches.	Yield per sq. ft.	Cost per 100 sq. ft.
	1	67	$1.43
1 Cement	¾	90	1.08
1 Sand	½	134	.72
	¼	268	.36
	1	104	.93
1 Cement	¾	139	.69
	½	208	.46
	¼	416	.23
	1	140	.61
	¾	187	.45
	½	280	.30
	¼	560	.15

This is the only pro-forma cost of waterproofing that I can make at all definitely.

As this paper was originally intended to be mostly devoted to this question of cost, I must ask your indulgence for the paucity of the knowledge available. The fact is that in all the processes dwelt upon, except the integral process, the work of waterproofing is done by special contractors, and the cost varies largely, being dependent upon materials used, specifications adopted and location and size of work.

About a quarter of a century ago, cellar work in New York, Boston, Providence, and other large cities, where buildings were erected subject to heavy tide pressure, the contracts were almost invariably given to one of three or four concerns who made a specialty of guaranteeing "watertight cellars," and for such work they obtained from one dollar up to a dollar and a quarter per sq. ft. This would seem a large sum in these days, but the guarantee often meant costly outlays and the actual cost of some of the work exceeded those amounts.

The average cost of coal-tar, pitch and felt coating would be about 6 cts. per sq. ft., and asphalt and burlap about 9 cts. per sq. ft. With heavy thickness of rock asphalt, the cost would run to 20 cts. per sq. ft., but, as stated, the cost is so problematical that estimates should be obtained from responsible contractors, who are prepared to build on their own specifications for the different lines of waterproofing construction best suited for varying contingencies and surroundings.

METHODS OF ATTACHING SHAFTING AND MACHINERY IN REINFORCED CONCRETE BUILDINGS.

By Wm. M. Bailey, M. Am. Soc. C. E.*

The manner of attaching shaft hangers, pipes and machinery to beams and floors in a factory or mill building of the reinforced concrete type is a detail of considerable importance, so much so in fact, that often if no satisfactory scheme is explained to the owner he will not consider the use of reinforced concrete beams in his proposed building. In the ordinary mill-construction factory with wooden or steel floor beams there is no special difficulty in attaching hangers for shafting and pipes or fastening machinery to the beams and floors in any desired location without the necessity of previous plans and at a minimum cost. In a concrete building however the conditions are entirely different and it is much better to adopt some scheme for the installation of the machinery, piping, etc., before the building is constructed, if we wish to obtain the best results in all respects.

Shaft Hanger Supports.

Appliances for conveniently supporting hangers for pipes and shafting and for supporting motors and other machinery from the beams and ceiling probably require more previous planning and careful selection than is necessary for other phases of this subject. The method recommended by the engineer and adopted for use in a reinforced concrete building should be one designed to best meet all the requirements, so far as can be known, of the building and its later equipment. It should be inexpensive, compact and simple in form, with not too many separate parts, and as flexible as possible to accommodate future changes in the line of shafting, additions or improved machinery, etc.

* Chief Engineer, Eastern Concrete Construction Company, Boston, Mass.

The author has endeavored to collect and present the different systems which are used by specialists in concrete construction.

One of the most common methods employed is to attach a hard pine timber to the under side of the concrete beam. This may be of any desired length, to which the shaft hangers are

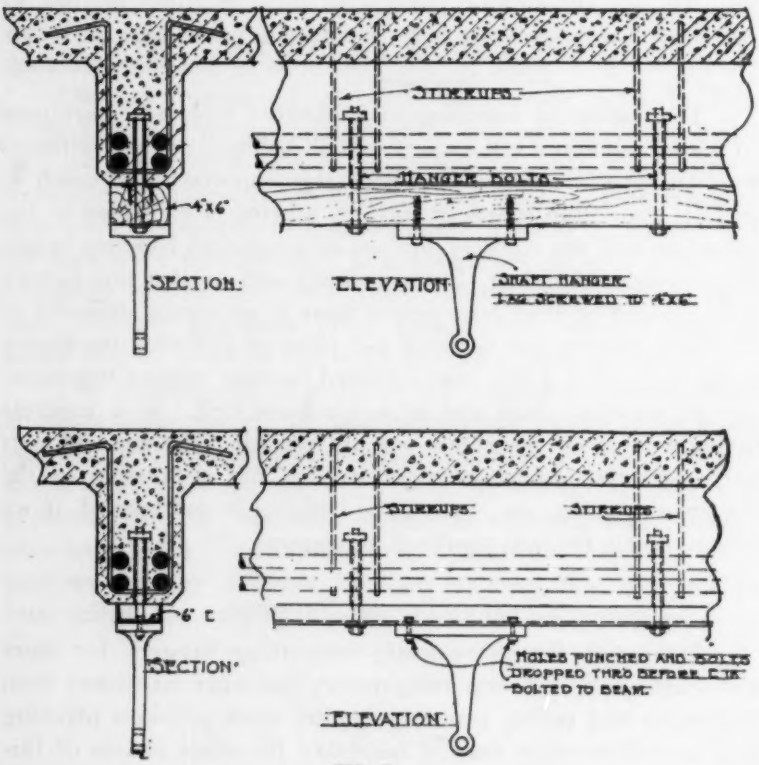


FIG. I.

bolted or lag-screwed in their exact position as shown in Fig. 1.* The timber can be secured to the bottom of the beams by bolts built into the concrete about 4 ft. on centers with a projecting threaded end and nut below, or by the use of sockets, inserts, sleeves and washer nuts imbedded in the concrete, into which the timber pieces are afterwards fastened. If the bolts are used, care

*Acknowledgment is made to *Concrete Engineering* for the cuts in this paper.—ED.

should be taken to set and keep them vertical, also have them thoroughly anchored into the upper part of the beams.

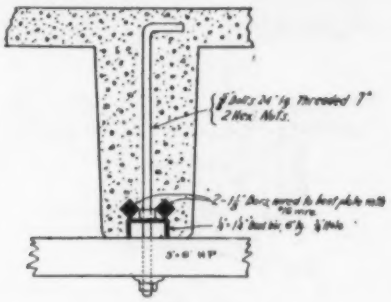


FIG. 2.

Fig. 2 illustrates the long bolt with saddles and check nuts to hold it in position, which is quite essential. It is seldom that

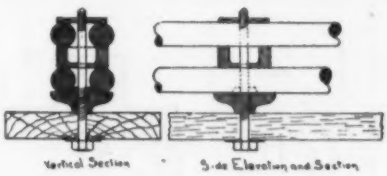


FIG. 3.

all the bolts projecting from the bottom of the beam are made use of and where not used they present an unsightly appearance, hence sockets or sleeves and washer nuts are often preferable.

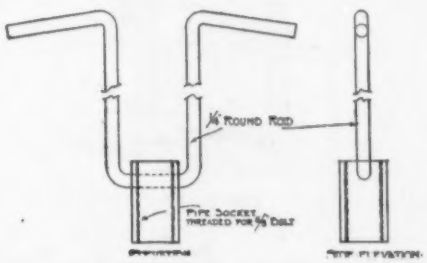


FIG. 4.

These can be kept in correct position with less trouble, are about of the same cost and surely make a neater looking job.

In Fig. 3 we have the Unit socket, the well known insert for concrete work. This device serves also as a support and spacer for the beam rods, keeping them all properly spaced from each other and from the beam box or centering. Fig. 4 represents a

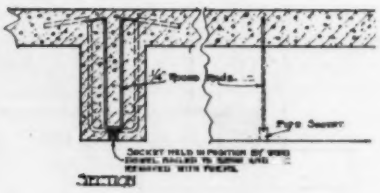


FIG. 4a.

socket sometimes used. It is made of a short piece of wrought iron pipe tapped out on the inside to receive a lag screw or bolt. Holes are drilled near the top, through which a ¼-in. rod or

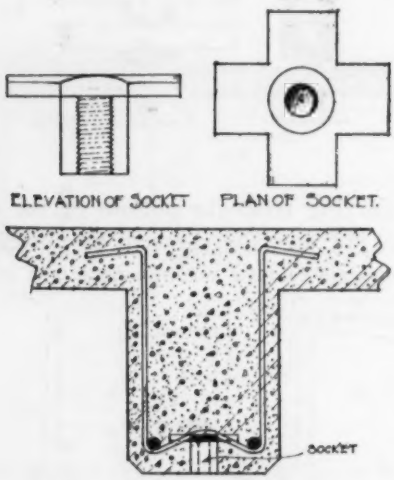


FIG. 5.

stirrup is placed which should extend well up into the concrete. The socket itself is temporarily held in position before the concrete is placed by setting it over a wooden plug nailed to the

centering. The stirrups are not easily kept in an upright position. For this reason this socket is not altogether satisfactory.

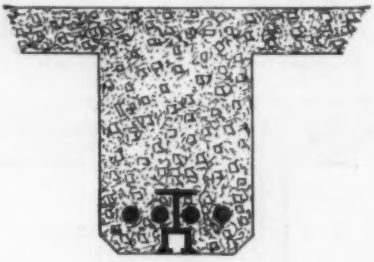


FIG. 6.

The socket shown in Fig. 5 is made of cast or malleable iron with a flanged top which serves to anchor it into the concrete. A vertical stirrup should be used with this socket if it is placed in

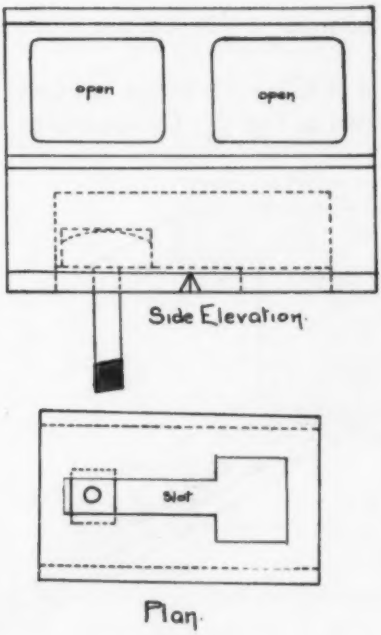


FIG. 7.

a beam and is intended to support much load. If used as shown in the sketch it also acts as a support for the rods.

The Bigelow socket shown in Fig. 6 can be made use of for almost all supports in reinforced concrete work. It is a malleable casting made in many sizes, can be anchored as securely in the

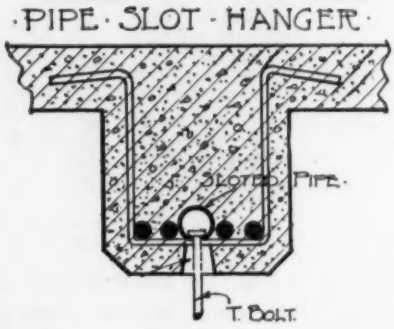


FIG. 8.

concrete as may be necessary by the use of stirrups and is more or less adjustable.

Another form of adjustable socket or insert, for use in beams principally, is shown in Fig. 7. These castings are made in con-

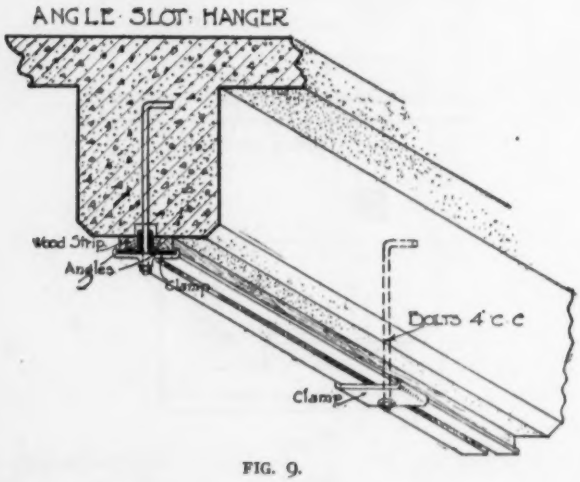


FIG. 9.

venient lengths and are set on the forms for centering before the concrete is placed. The slot in the bottom makes it possible to

place hangers or bolts at any desired location along the length of the insert.

Fig. 1 illustrates the use of large washer nuts imbedded in the upper part of the concrete beam, usually about 4 ft. on centers. These are temporarily held in position by a thin iron tube resting

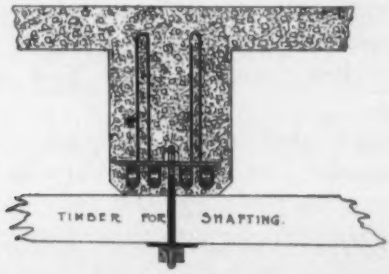
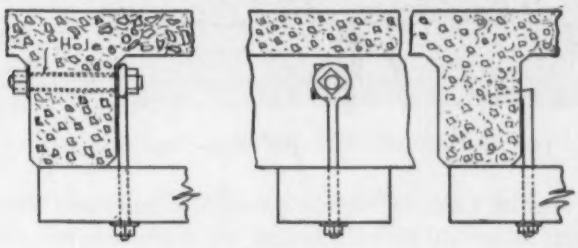


FIG. 10.

on the centering and by a bolt projecting through the hole in the bottom of the beam box. The washer nut is tightened down to the top of the tube which secures it firmly in an upright position. When the beam boxes or centering are taken down the bolts are



FIGS. 11 AND 12.

easily unscrewed from the nut, leaving a clean passage through the concrete to the nut above, to which can be attached timber or iron stringers, on to which the shaft hangers can be fastened in the ordinary manner.

Figs. 8 and 9 illustrate two other methods used for attaching shaft hangers and machinery to beams. With either of these

schemes the shaft hangers or other fittings can be bolted or clamped to the concrete structure without the use of wood timbers or iron bolsters if so desired. The method shown in Fig. 9 is one that was adopted by the United Shoe Machinery Company in its extensive shops at Beverly, Mass.

Another method is suggested in Fig. 10, which can be made a strong and serviceable support for motors and machinery.

Other systems which have been used quite extensively by the Turner Construction Company, New York, are illustrated in Figs. 11 and 12.

When a bolt is used through the beam near the top a metal sleeve with a wooden core is concreted around to form the hole.

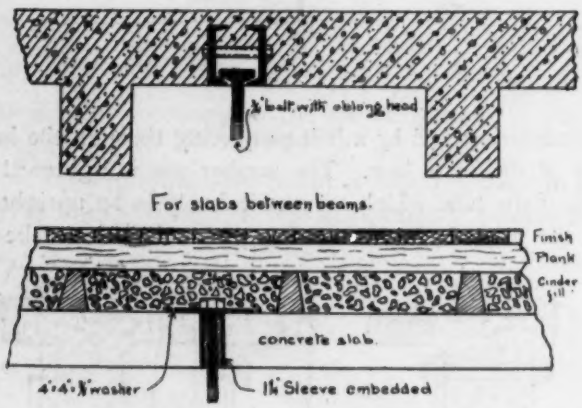


FIG. 13.—METHODS USED FOR SLABS BETWEEN BEAMS.

These openings also permit the passage of pipes and wires. Large holes left in certain parts of beams and girders might cause weakness in the compressive side of the member. If so, an iron pipe sleeve of sufficient thickness should be used. It is rather difficult to always locate the holes through the beams during construction to conform exactly with future changes. Therefore, the system using the hooked hanger bolt in the side of the beam is more satisfactory and is the one adopted for use in the building of the Gair Publishing Company, Brooklyn. If the holes for the hook bolts are cut with a pneumatic drill it can be done at a nominal cost.

WIRES AND SPRINKLERS FOR SUPPORTS.

Blocks of wood are often set in the under side of concrete slabs to which are fastened wires and small sized pipes and wire conduits. This is not considered a suitable or permanent support. It is much better practice to use either expansion bolts or locate and place adjustable sockets and inserts in the concrete work. Often the conduits for wires are placed on the centering and imbedded in the concrete slabs. If the pipes are not too large and are located with due regard to the reinforcing metal there is no serious objection to this method. Piping for sprinklers is generally planned before the concrete work is started. It is

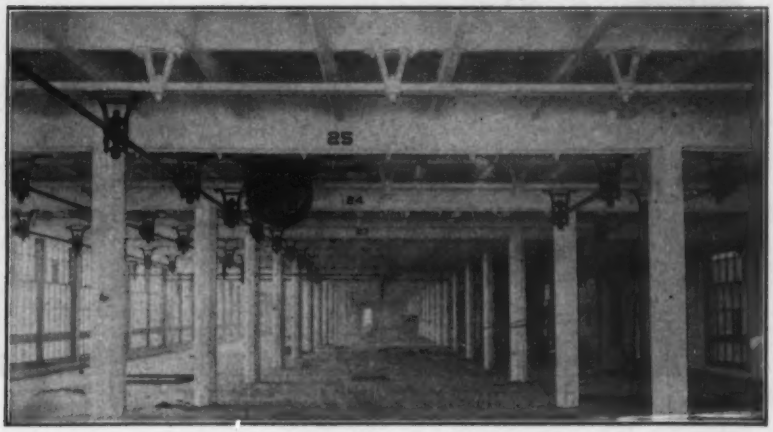


FIG. 14.—GENERAL VIEW OF SHAFTING.

therefore a simple matter to place inserts or sockets where needed in the concrete work, to which the pipes can be readily attached later on.

MACHINERY FASTENINGS.

Large machines with heavy bases setting on the floor seldom require any special fastenings. It is usually sufficient to thoroughly grout with Portland cement mortar the base of the machine to the concrete floor. Small machines can be fastened directly to the concrete by expansion bolts or similar methods after the floors are concreted, the cost of drilling for these fasten-

ings being a small item of expense. Sometimes, however, it may be necessary to bolt through the floor in order to hold certain machines rigidly. If through bolts are required the holes should, if possible, be located before the floor is concreted; otherwise, in cutting these holes through the floor reinforcing bars are liable to be encountered, which would cause more or less difficulty and might lead to serious trouble if cut off. In most cases machinery runs better and lasts longer if placed on solid foundations, and reinforced concrete floors are admirably adapted for machine

FIG. 15.—DETAIL VIEW OF SHAFTING.

shops. There are, however, exceptionable cases where machines seem to require more or less "give" on their bases in order to be most satisfactory in working and endurance. This is particularly true with certain textile machinery, and where a cushion is required a wood finished floor can be laid, or wooden timbers or bolsters can be fastened to the concrete flooring. It has also been suggested to use sheet cork or linoleum carpet under the base of machines in order to give elasticity of movement and also lessen the noise of running machinery.

REPORT OF COMMITTEE ON ART AND ARCHITECTURE.

ALBERT MOYER,* Secretary.

In pursuance of the suggestions contained in the report of the Committee at the last Convention, requests have been sent out during the past year for photographs of concrete structures possessing artistic and architectural merit. A great many photographs were received and have been so classified by the Committee, as to give as far as possible equal prominence to the various classes of concrete construction. Two of the most artistic designs of each class are herewith presented.

I. Monolithic and Reinforced Concrete Residences.

First award. Residence of Mr. Wm. C. De Lanoy, Short Hills, N. J. John A. Gurd, Archietct; B. A. Howes, Jr., Engineer and Builder. Fig. 1.

Second Award. Residence of Mr. Fred Pabst, Oconomowoc, Wis. Fernekes and Cramer, Architects; Newton Engineering Company, Builders. Fig. 2.

II. Concrete Block Construction.

First Award. Residence of Mr. Edw. S. Harkness, New London, Conn. Lord and Hewlett, Architects; Emerson and Norris, Builders. Fig. 3.

Second Award. Residence of Mr. J. Y. Reed, Winnipeg, Canada. H. B. Rugh, Architect; Perfection Concrete Company, Builders. Fig. 4.

*By reason of the illness of the Chairman, Mr. Charles D. Watson, this report was prepared and presented by the Secretary.

III. Factories, Warehouses, etc.

First Award. Warehouse of Great Atlantic and Pacific Tea Company, Jersey City, N. J. Howard Chapman, Architect; Turner Construction Company, Engineers and Builders. Fig. 5.

Second Award. Woolen Mill of Mayo and Son, Foxcroft, Maine. Adolph Suck, Engineer; Eastern Concrete Construction Company, Builders. Fig. 6.

Second Award.
Monolithic Concrete Residences.

Fernekes and Cramer, Architects.
Newton Engineering Company, Builders.

FIG. 2.—RESIDENCE OF MR. FRED PABST, OCONOMOWOC, WIS.

IV. Office Buildings.

First Award. Building for Phelps Publishing Company, Springfield, Mass. Fred. S. Hinds, Architect; Turner Construction Company, Builders. Fig. 7.

V. Bridges, Walls and Fences.

First Award. Walnut Lane Bridge, Wissahickon, Pa., City of Philadelphia. George S. Webster, Chief Engi-

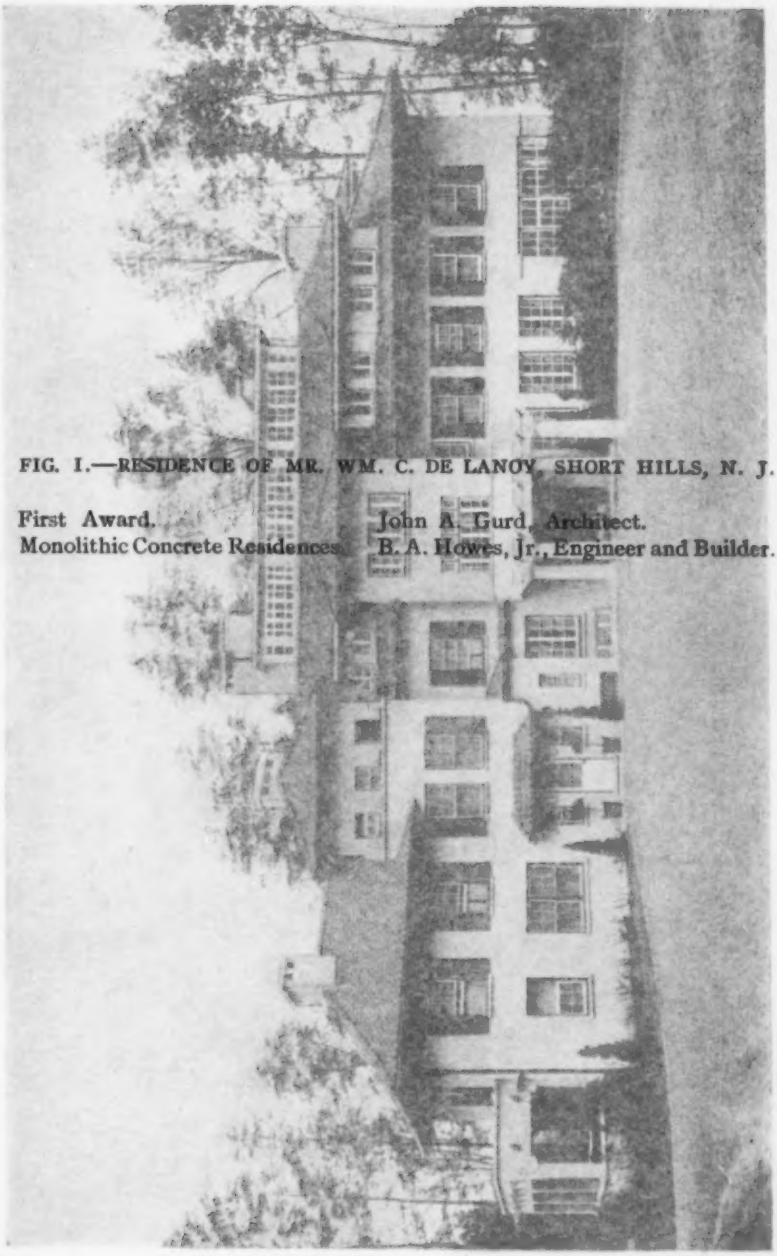


FIG. I.—RESIDENCE OF MR. WM. C. DE LANOY, SHORT HILLS, N. J.

First Award. John A. Gurd, Architect.
Monolithic Concrete Residences. B. A. Howes, Jr., Engineer and Builder.

neer Bureau of Survey; Henry H. Quimby, Engineer of Bridges; Reilly and Riddle, Builders. Fig. 8.

Second Award. Connecticut Avenue Bridge, Washington, D. C. Colonel W. M. Black, Colonel Lansing H. Beach, Colonel John Biddle, successive Engineer Commissioners, District of Columbia; W. J. Douglas, Engineer of Bridges; George S. Morison, Consulting Engineer (Designer); District Construction Company, Builders. Figs. 9 and 10.

VI. Manufactured Decorative Concrete Stone.

First award. Temple in a Formal Garden on a Private Estate in Massachusetts, Concrete Stone. Little and Brown, Architects; The Emerson and Norris Company, Builders. Fig. 11.

Second Award. Decorative Concrete Stone Work. Designed and manufactured by the George Rackle and Sons Company. Figs. 12 and 13.

We feel that there is a growing interest among architects and the public in the artistic development of concrete construction. So far the development has been principally along the lines of Decorative Concrete, Concrete Bridges, Warehouses and Factory Buildings, due to the fact that the material is more economical and better adapted for this class of work than any other structural material.

Concrete from the viewpoint of economy and service is also better adapted for other structures, such as residences, walls and fences, but has not been so well exploited, the architects not being in possession of sufficient information and precedent to overcome a certain prejudice against this most excellent material.

This prejudice has been due to some extent to the exploitation of concrete blocks, which are often imperfectly and improperly made and of abominable design, mostly a bad imitation of rock face. This has caused the architects to look askance at concrete block construction for residential purposes.

That concrete is an excellent material for structural work is unquestioned, but that it can be made beautiful to the eye is doubted by most architects. Architecture to be sane and rational in accord with good art, must be designed to meet the requirements of the climate, the habits of the occupants and to secure the most economical use of the available materials.

Wherever concrete is employed and surface markings as produced by the forms allowed to remain, without attempting

Second Award.
Concrete Block Construction.

H. B. Rugh, Architect.
Perfection Concrete Company, Builders.

FIG. 4.—RESIDENCE OF MR. J. Y. REED, WINNIPEG, CANADA.

to disguise the methods employed, the effect will sem unattractive to the unpractical eye of the majority of people, even though relief is given by the use of colored clay tile or other colored decoration. It is good for it is honest. That such treatment in time will become interesting and beautiful I have no doubt.

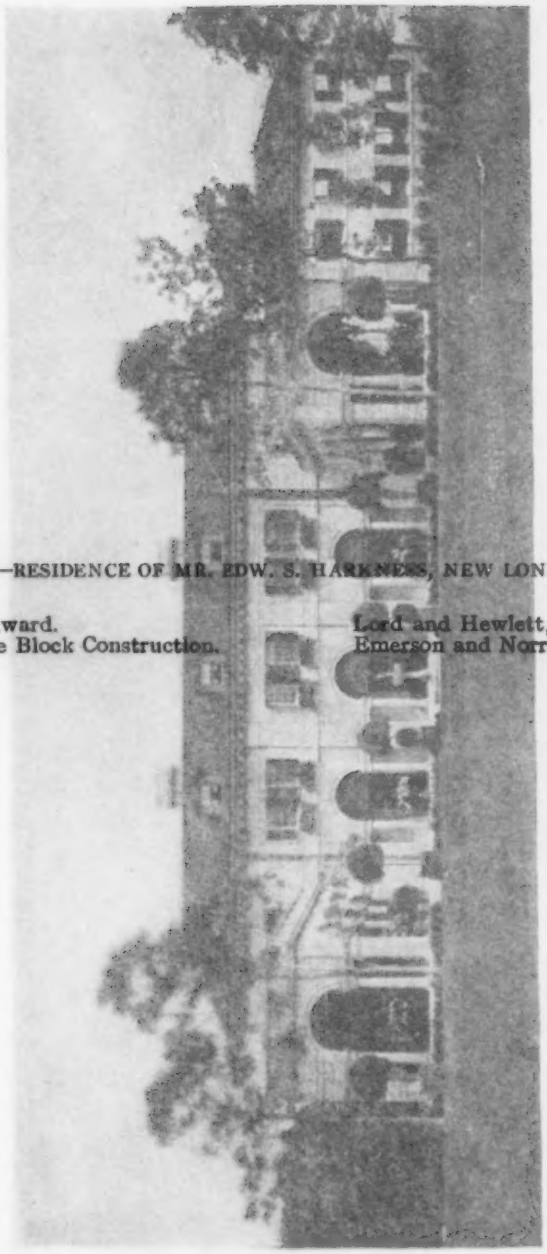
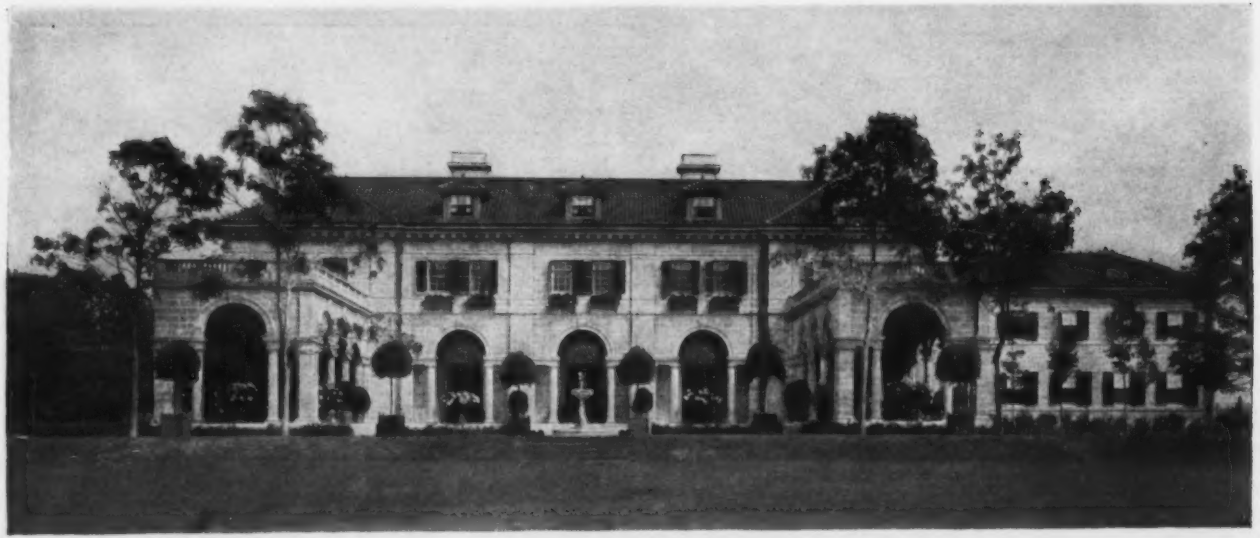


FIG. 3.—RESIDENCE OF MR. EDW. S. HARKNESS, NEW LONDON, CONN.

First Award.
Concrete Block Construction.

Lord and Hewlett, Architects.
Emerson and Norris, Builders.



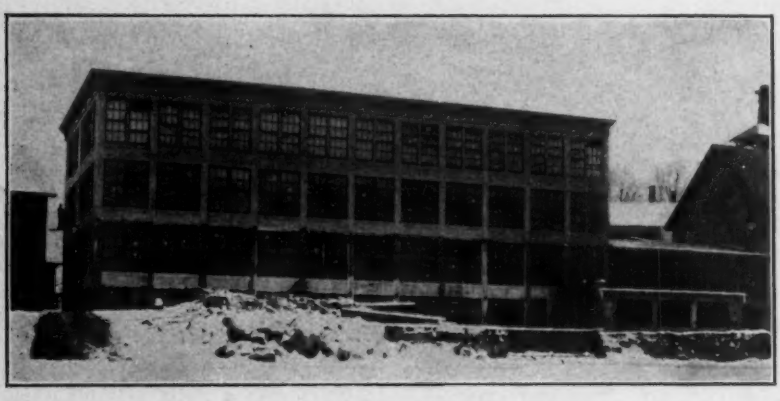
That which the eye has never seen is seldom pleasing; that which is unaccustomed suggests doubt. If, however, the fundamental laws of art are followed, as the eye becomes accustomed the art and the structure become pleasing. Natural caverns homes of earth and ice were the first dwellings; later wattled rude frames were thatched with grass, stamped with earth. The first mud house as well as baked mud or clay, later called brick, must have been an unpleasant shock to the primitive man who had never seen this form of construction. For that which we have seen for the first time is seldom understood, the memory carrying nothing similar and with it no imagination. The rude frame thatched or wattled houses must have gradually become pleasing to the eye of the primitive man as they are picturesque to the poetry of to-day. We can trace back through the ages the development of architectural thought.

The binding together of saplings with grass rope or animal skin thongs, were for the purpose of economical construction, the object being to obtain a strong support for a roof, large hewn timber being unknown. Thus we have the image which suggested the fluted stone column. The Doric frieze and cornice were reminiscences of a primitve wood construction. The triglyph (tablet with three vertical channels) suggests the chamfered ends of cross beams of three planks each. The numerous tent poles supporting the canvas roof of the Arabs and Moors furnished the idea of the slender marble columns in myriads supporting the roofs of the mosques and alcazars.

The memory translated one material to another. There was no shock, the eye being intuitively accustomed, the architecture became pleasing, and if of happy design very beautiful. But the reverse applies to the best of art and even to the educated mind *should* the *development* be *relatively sudden*, in instances where new and economical structural materials are discovered, such as Portland Cement, the eye having been accustomed to massive construction as in heavy stone columns, the development is rapid. In reinforced concrete we do not see the source of strength. It appears to be of slender construction but when properly designed is, in fact, of as great if not greater strength.

As soon as the eye becomes accustomed and the mind knows the source of strength, the slender but strong structures become beautiful.

An inhabitant of another planet if he be differently constructed, and viewing for the first time the most beautiful human being on this earth, might consider such being very ugly, not knowing that the flesh covered bone and muscle, the sources of strength. He might not be able to understand how the being could ever stand on its feet. It is so with reinforced concrete when seen for the first time.



Second Award.
Concrete Factories.

Adolph Suck, Engineer.
Eastern Concrete Construction Company, Builders.

FIG 6.—WOOLEN MILL OF MESSRS. MAYO AND SON, FOXCROFT, MAINE.

Some of the great masters in the art of painting were unable to sell their masterpieces at any price, although later they often sold for fabulous sums. They had developed an original style of beautiful painting, which did not seem beautiful in their day, the painter being far beyond his time. As the eye became accustomed art became beautiful.

To illustrate again, when we first saw our mammoth battleships we considered the lines very ugly and the ship a monstrosity, our eye having been accustomed to the old "clipper and

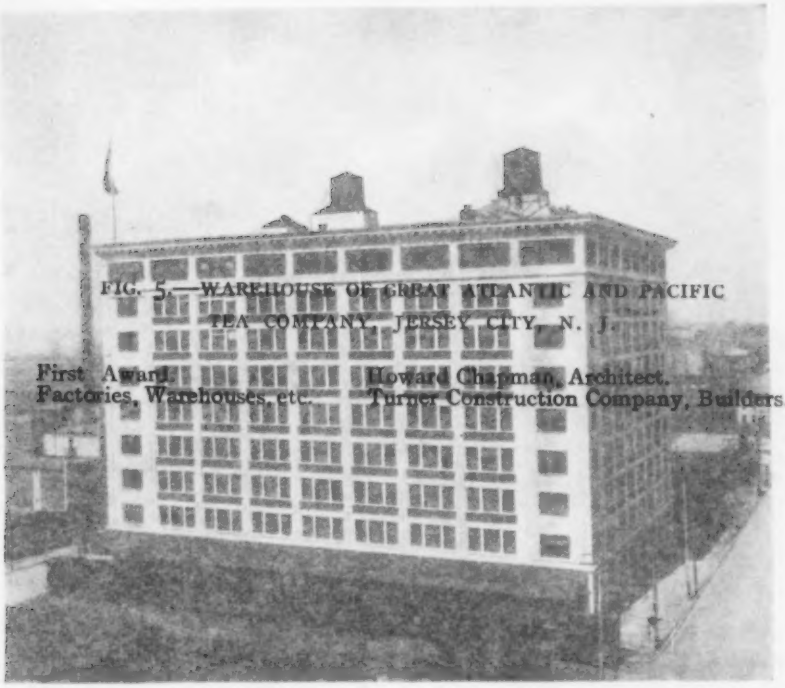


FIG. 5.—WAREHOUSE OF GREAT ATLANTIC AND PACIFIC TEA COMPANY, JERSEY CITY, N. J.

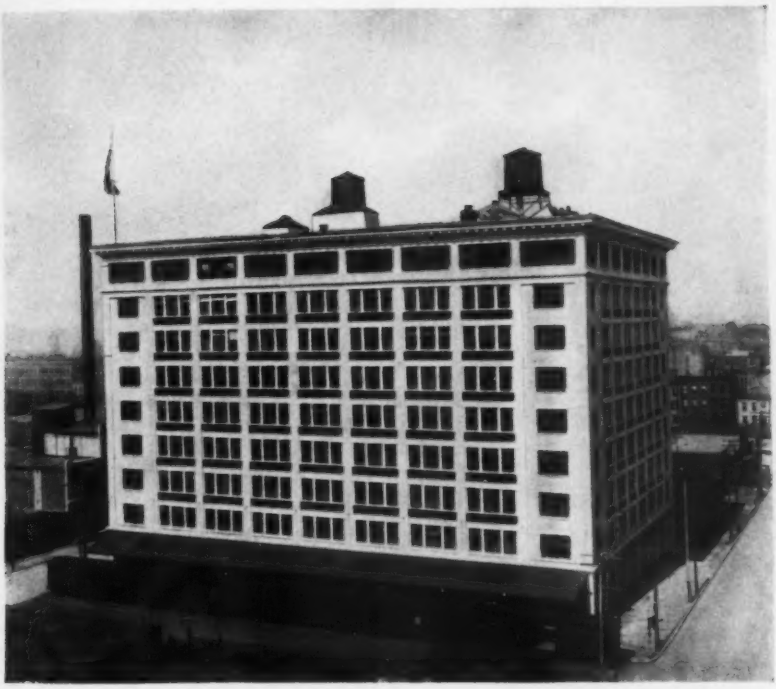
First Award.
Factories, Warehouses, etc.

Howard Chapman, Architect.
Turner Construction Company, Builders.

FIG. 7.—BUILDING FOR PHELPS PUBLISHING COMPANY, SPRINGFIELD, MASS.

First Award.
Office Buildings.

Fred S. Hinds, Architect.
Turner Construction Company, Builders.



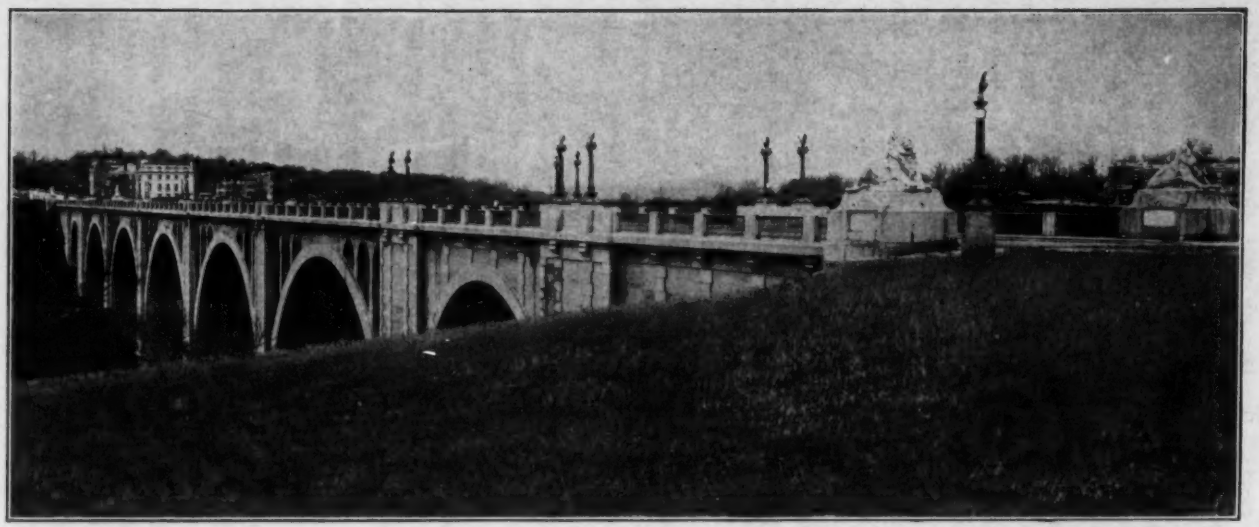
cutter style of vessels. To-day we view these same battleships, huge, massive floating forts of enormous strength, as things of beauty.

We will skip through the Egyptian, Greek, Saracenic, Roman, Gothic, etc., which are all an evolution of suggested and enlarged thought, and reach a period when a new material suddenly appears, and, strange to say, history is repeating itself in that concrete will displace timber construction. It is fortunate that we have this material during a period when our forests have not yet been depleted. Concrete is the lumber of the future, and will assist very materially in the conservation of our forests.

Concrete construction properly designed is not an imitation of either wood or stone. Its artistic treatment must be true, sincere and honest, all thought of imitation eliminated. The architectural treatment, however, should not discard precedent, but work along the lines of evolution. The original designs required will produce an edifice which at first will be mentally misunderstood, but, nevertheless, looking forward and feeling assured that if correctly designed we are working along the lines of good art, we can state positively that such structures even twenty-five or fifty years from now will be viewed as beautiful, the eye having become accustomed. If, therefore, it is beautiful then, it is in fact beautiful now. In exactly the same relation as the works of the great masters which were not considered beautiful when first painted have become wonderfully so to the eye of the present day. We might, therefore, state that in viewing concrete construction treated properly as concrete our eye is primitive as compared to the educated eye of the future.

A reinforced concrete column left without surface finish, all the board and form marks visible, is to our eye an unattractive gray color. Decorate the cap with an inlay of tile of various colors, and possibly a band or two around the column and on the base, showing that the column is left intentionally true, honest and sincere, the reverse of imitation, and you will find, as the eye is educated it becomes a thing of beauty. The unattractive gray is in reality beautiful if understood and properly combined with other colors. I have gone to the extreme in order to illustrate.

We also may work along the lines of good art by means of surface treatment which leads up to one of the forms of a true



Second Award.
Bridges, Walls and Fences.

Colonel W. M. Black, Colonel Lansing H. Beach, Colonel John Biddle, successive Engineer Commissioners, District of Columbia.
W. J. Douglas, Engineer of Bridges.
George S. Morison, Consulting Engineer (Designer).
District Construction Company, Builders.

FIG. 9.—CONNECTICUT AVENUE BRIDGE, WASHINGTON, D. C.

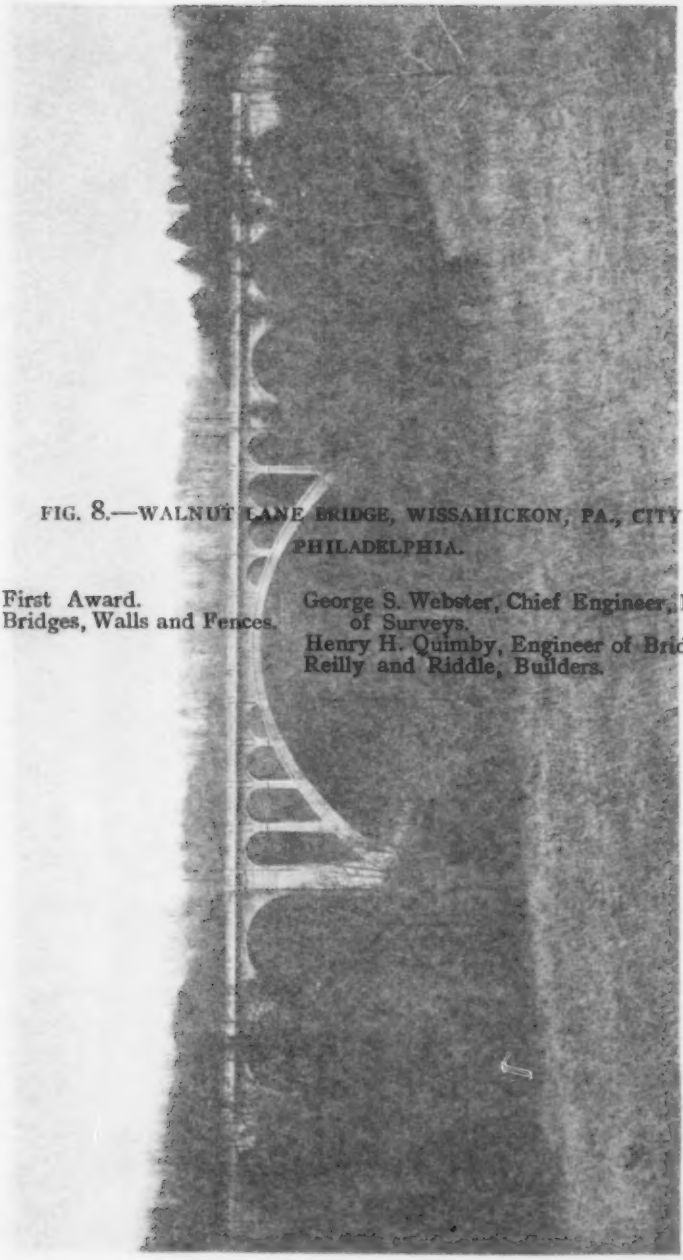


FIG. 8.—WALNUT LANE BRIDGE, WISSAHICKON, PA., CITY OF PHILADELPHIA.

First Award.
Bridges, Walls and Fences.

George S. Webster, Chief Engineer, Bureau of Surveys.
Henry H. Quimby, Engineer of Bridges.
Reilly and Riddle, Builders.

concrete architecture. The methods of economically treating the surfaces of concrete are so numerous as to give the architect a larger scope, far greater than that of any other building material both in color and design. Among the various effects that can be produced are the numerous stucco finishes which are well known, the exposing of selected aggregates, by which method the surface is scrubbed while the concrete is green, exposing the larger pieces

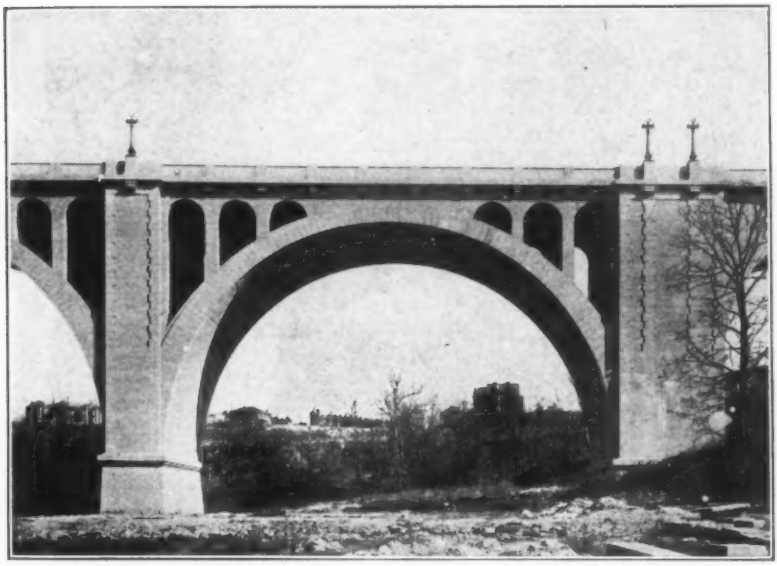


FIG. 10.—VIEW OF ONE SPAN OF THE CONNECTICUT AVENUE BRIDGE, WASHINGTON, D. C.

of aggregates; in fact, throwing them slightly in relief, giving a rough surface of accidentally distributed varied colored stones, removing all of the cement color from the surface of the mortar, binding together these stones, causing the mortar and the larger pieces (1½ ins. down to ¼ in.) to be alive with purpose and color.

Also brushing the surface with dilute muriatic acid, which removes the cement from the surface of the various particles. This acid treatment is usually used on a finer grain surface than

Second Award.
Manufactured Decorative
Concrete Stone.

Designed and made by
The George Rackle and Sons Company.

FIG. 12.—MANUFACTURED DECORATIVE CONCRETE STONE.

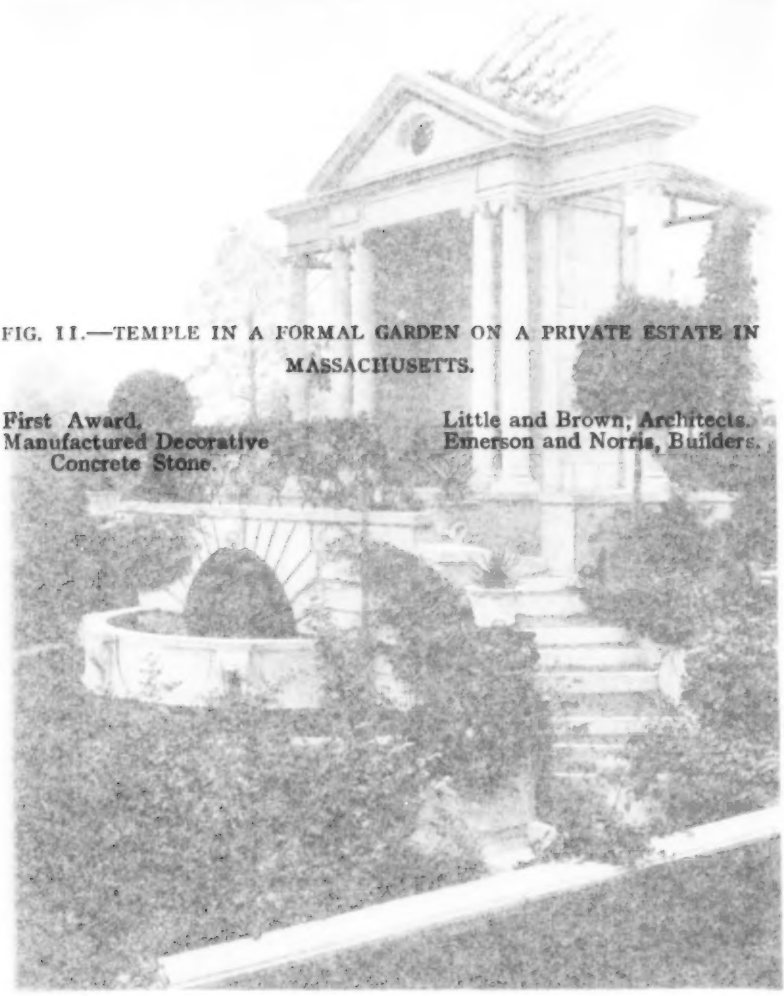


FIG. 11.—TEMPLE IN A FORMAL GARDEN ON A PRIVATE ESTATE IN MASSACHUSETTS.

First Award.
Manufactured Decorative Concrete Stone.

Little and Brown, Architects.
Emerson and Norris, Builders.

Second Award.
Manufactured Decorative Concrete Stone.

Designed and made by
The George Rackle and Sons Company.

FIG. 13.—MANUFACTURED DECORATIVE CONCRETE STONE.

exposed selected aggregates, the appearance is entirely different, no similarity. The exposed selected aggregates can be viewed from a distance of 500 feet. The appearance of the surface from that distance is as pleasing as in the nearby view. Whereas, the finer grain surface appears at a distance very much the same as if the surface had not been treated at all. This same effect applies to what is known as Bush hammered surface.

The exposed selected aggregates afford a wide field. The various colored stones, pieces of broken brick, white marble chips and broken clay tile can be formed into a combination giving possibilities which are not to be obtained by any other method. Combining these effects with clay tile in design primitive Indian or Oriental colors, and the effect is very happy. But we cannot obtain these effects by artificial methods such as what might be called pebble dash, the pebbles being placed in the mortar by hand, they are unconsciously arranged with such a degree of regularity as to be obviously unnatural.

The exposed selected aggregates, bush hammered concrete or acid treated concrete is perfectly rational, along the lines of good art, honest and sincere, as it simply exposes the aggregates in the position which the mixing has placed them.

Clay and Sand Surface.—Plaster inside of forms with wet clay, work to a plastic consistency which will adhere to the forms. Corners may be rounded by this method, and by indentations bead work and other designs can be accomplished.

While the clay is wet, apply evenly, loose buff, red or other colored sand, after which, pour in the concrete by the same method as applied to ordinary wet concrete construction, remove remove forms in usual time after clay is dry, wash off the clay with water and if necessary scrub slightly with a brush. The sand will thus adhere to the concrete giving a surface of pleasing color and texture.

There is still another use for concrete which is entirely different from that above described, and yet in perfect accord with good art. I refer to the molding or casting of concrete stone. If by intelligence and good workmanship we can reproduce natural pink or gray granite, or even with our White Portland Cements an excellent marble, performing the work so faith-

fully as to baffle the practiced eye, we are actually reproducing a natural stone. I have seen a large amount of this work in Boston, particularly at Harvard College, where there is a building of granite, a wing having been added of concrete stone in the form of granite so faithfully reproduced as to make it impossible for even the practiced eye to tell where the natural stone ends and the concrete stone begins. This at a distance of not over five feet.

I could also go further and state that the concrete blocks which have been such an abomination in the past can be successfully used and serve the purpose of correct art, provided the concrete blocks are employed as concrete blocks, not an imitation of anything else. The rock-face concrete blocks are unquestionably a bad imitation.

The concrete stone molded or cast has the advantage over natural stone, by the correct selection of the best of aggregates scientifically proportioned so that maximum density results, no lamination occuring as occurs in natural stone. Therefore, it is safe to state that such a stone can be produced more uniform, as dense as Nature's products and artistically as beautiful, there being no thought of imitation.

The architectural treatment of concrete as concrete is one matter, and the reproduction of a natural stone is another, so is the employment of concrete blocks still another. By one method we are manufacturing a natural stone by artificial methods, by another we are manufacturing a concrete hollow block to be used as a concrete hollow block, not a natural stone, and not an imitation. When the Greeks translated wood into stone the form was suggested but the material was obvious. So it should be with concrete, but if used to reproduce a natural stone *then* and *then only* should the reproduction be architectural treated as natural stone.

This subject of the architectural treatment of concrete as a structural material may, therefore, be divided into two parts, and when used it should either stand honestly as concrete or should be used to reproduce Nature's products, but in reproducing, if bad workmanship is employed, merely ugly imitation results. This line is rather finely drawn, but we should not become so fanatic as to state that concrete can be used only as concrete.

Quoting from Ruskin: "To cover brick with plaster and this plaster with fresco is perfectly legitimate, the plaster is gesso grounds on panel or canvas, but to cover brick with cement and to divide this cement with joints that it may look like stone, is to tell a falsehood, and is just as contemptible a procedure as the other is noble."

DECORATIVE CONCRETE STONE.

By Frederick A. Norris.*

It is now a generally accepted fact that properly made concrete possesses all qualities of the best natural quarried stone that would make it desirable as a building material with the exception of a pleasing appearance, which it often lacks.

It is durable, hard, strong in compression, can be made strong in tension by proper reinforcement with steel, is practically non-porous, fireproof, a good non-conductor of heat, and is without strata. Besides, it is generally cheaper than quarried stone.

It is also well known that it can be molded or cast into practically any desired form, but then its appearance in color and texture, unless this process is done by experts in this special work, is nearly always so undesirable that it cannot be used successfully for ornament on buildings of any pretensions, especially those of a classical character, where columns, capitals, cornices, molded courses and the like are employed.

In view of these facts, it is apparent that if we could make its color and texture pleasing to the eye, and its form accurate in every detail, so that it would not look molded or cast, but have sharp arises and true lines, a very much larger field would be opened up for its use.

As our criterion of appearance fixed by habit is that of quarried stone, and as concrete is really itself stone, we naturally try to approach in color and texture the article made by nature, not necessarily because we want to imitate it for the purpose of deception—although in practice this is often the case—but because, in our imaginations, we have no better standard of looks.

It is, however, possible to make concrete appear as concrete, so that it can be readily distinguished as such, and still have it pleasing to the eye.

* Emerson and Norris, Boston, Mass.

There are, generally speaking, four different methods of surface treatment successfully employed:

1. To reveal the aggregates.
2. To make the concrete surface take on its color and texture from different substances placed in contact with the wet cement in the molds or forms.
   (These first two methods are generally the ones employed when it is desired to approach natural stone in appearance, although they are not necessarily limited to this purpose.)
3. To cover up the surface either with some kind of paint or plaster.
4. To embellish the surface with materials of distinctive shades or colors generally in design, materials such as terra cotta, Moravian tile, colored glass, mosaic, brick, pebbles or other similar substances.

There are two ways of revealing aggregates, one by tooling the surface after the concrete has been thoroughly set and has hardened, which generally requires about four weeks before tooling can be done, and the other by scraping off the surface of neat cement before the concrete has thoroughly set, generally using a bristle brush for the purpose, and then washing the concrete either with plain water or a solution of muriatic acid. This latter method is generally employed within 24 hours of the time that the concrete is placed in the forms.

In order to attain good results by revealing aggregates, the aggregates must be worth revealing, and be pleasing in themselves; furthermore, they must be placed in the forms and manipulated after being placed, in such manner as to be uniform in distribution, and the markings of the forms, or the markings of successive layers laid at different periods of the work must not appear. They must be properly and carefully selected as to size. To be pleasing, aggregates must reflect light well and be distinctive in shade or color.

Black and white marble have been most successfully employed for this purpose, and instead of becoming dull with age, they weather lighter, and retain distinctive textural advantages

over even most granites. There are examples of this work in structures in the vicinity of Boston that are twelve to fourteen years old, and look nearly like new. Crushed granite of some kinds serves very well, but requires, as a rule, a small portion of black or white aggregate, or brilliant material of distinctive and different colors mixed with it to give it the desired "life."

It is almost a practical impossibility to so proportion the aggregates of a given stone with a view of reducing the voids to the utmost minimum, thereby necessitating the least amount of cement, so that when revealed, the appearance of the product will closely resemble the natural stone from which the aggregates are taken. The variable in this operation emphasizes the uncertainty and difficulty of the attempt.

There is another matter to be taken into consideration in the employment of aggregates, that is their size to conform to different designs. If sharp arises and fine ornamental details are required, small aggregates must be used; a very common error of design is the making of too fine detail for a concrete of large aggregate.

As selected aggregates are generally costly, it is often advisable to form only the surface of the stone of this selected material, placing it in position at the same time that the backing of rougher concrete is installed. If this be properly done a perfect bond between the face and backing is insured. This can be proved by the inspection of this material in a number of places in and about Boston, where it has been employed for twelve or fourteen years, and shows no signs whatever of disintegration.

Of the second method this much can be said: If concrete is poured very wet, nearly the consistency of thick soup, into a material made of a porous substance, such as sand, or a mixture of sand and other desired material, the surface of the concrete which comes in contact with the mold will take on the texture and color of the material of which the inside surface of the mold is composed. When concrete is of this wet consistency, the surplus water naturally carries with it the finest particles which are comprised largely of neat cement. This goes to the surface and percolates through the porous substances on the inside face of

the mold, leaving behind it on the surface a sufficient quantity of neat cement to adhere to the particles forming this surface of the mold, taking them up and making them an integral part of the body of the concrete, and forming a surface thereof of the same color and texture of the material with which the mold is lined. There are many possibilities in this direction still to be developed.

The third method of covering concrete surfaces is well known and successfully employed on a large scale, and needs no exposition here. There are many, however, who believe that Portland cement and sand plaster cannot be put on a concrete surface and made durable because a proper bond cannot be formed between the backing and the surface, and that such plaster will crack and fall off in the course of time. It is possible, however, to make a durable surface in this way, and it has been done on many different pieces of work. It is absolutely necessary to have the face of the concrete thoroughly roughened up generally by tooling for the purpose of insuring a proper bond, and the surface must be thoroughly wet before the first coating of plaster is applied. This first coat must be thrown on with force, roughened up and allowed to set before the second coat is applied, because otherwise the weight of the second coat will tend to break the bond of the first coat. The second coat must then be applied in the same manner as the first coat. The finishing coat can then be floated on or applied in any other desirable manner, which is well known, after the second coat has been set and thoroughly wet down. The finish plaster should be kept covered and wet for at least one week. If large surfaces are to be treated, joints should be left to overcome contraction cracks.

There are great possibilities of obtaining effective and artistic results on rough concrete by embellishing it with colored substances in design. These can be inlaid after the concrete is set in recesses left for the purpose, or can be placed in the forms before the concrete is poured. The grill-room of the Tennis and Racquet Club, Philadelphia, is an illustration of its successful employment.*

These four general methods mentioned can be combined, as,

*Illustrations of this work appear in Proceedings, Vol. IV, pp. 116-123.—ED.

for instance, concrete with the aggregate revealed, embellished with colored substances or surfaces treated partly in one manner and partly in another. The two latter methods are the ones usually employed on concrete surfaces which are to look like concrete, and not intended to simulate the appearance of quarried stone.

Many architects, engineers, and even those engaged directly in the concrete industry believe that concrete as a building material should always stand up for itself, be known as concrete, and never be employed as an imitation material, but it is a fact, nevertheless, that it can be made to resemble natural stone so closely as to deceive the layman, or even the expert, at a distance away of a very few feet. It can have just as much life, just as much color, just as sharp arises as natural stone, and in addition, it can be without strata or bed, fireproof, and reinforced with steel, qualities which natural stone does not possess.

UNBURNABLE HOMES—THEIR ARTISTIC AND ARCHITECTURAL POSSIBILITIES.

By Benjamin A. Howes, Jr., C. E.

During the past six years my time has been given over exclusively to the construction of concrete unburnable homes. The experience I have met with in my efforts to persuade owners that a concrete house was the best possible investment has convinced me that there are two main stumbling blocks to be overcome before concrete will come to its own as the domestic building material par-excellence.

The first of these lies in the scarcity of engineers or organizations trained for the economic erection of such buildings. As every one knows, there are many firms of concrete engineers who have attained a large measure of success and whose work as to quality and efficiency leaves nothing to be desired. The substantial records of their success in the shape of concrete industrial structures, factories, warehouses, bridges, dams, etc., cover the country.

No such wealth of material, however, awaits the investigator of what has been done in this line of concrete domestic work. The reason for this is not far to seek. In the construction of industrial work, the problem facing the engineering contractor is one of rapid and economical handling of large amounts of material. The house builder, on the other hand, faces a problem made up of an infinite number of petty details. Instead of planning how much plant he can use to reduce the cost of each yard of concrete entering into the structure, the house builder must seek to avoid every possible dollar's investment in a plant that because of the insignificant bulk of concrete in the work will have no possible chance of paying for itself. For this reason, these industrial concrete engineers have steadfastly refused to build residences, no matter by whom the opportunity was offered them.

On the other hand are found many excellent firms of builders possessed of an organization wholly capable of the efficient and economical handling of the multitude of details that go to make up the house building contract, but these men are absolutely devoid of the engineering experience and ability necessary to the successful concrete constructor, and, as conservative men, they, too, have refused to undertake concrete house construction.

It is only because these facts point to the profitable necessity for a concrete house organization that I am forced to turn for the illustrations presented herewith to the work of my own

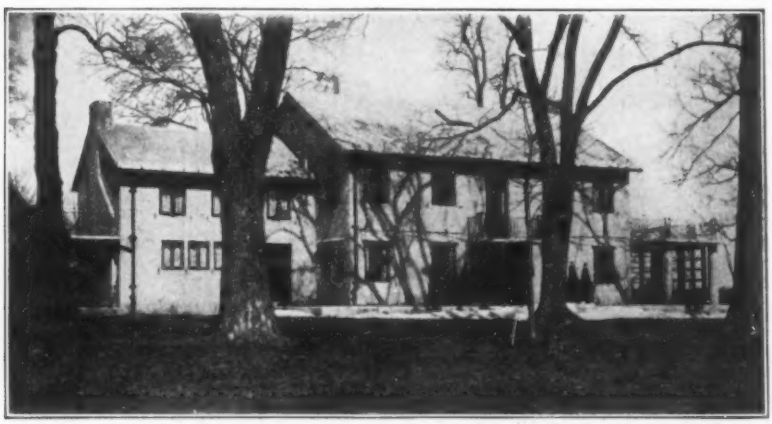


FIG. I.—REINFORCED CONCRETE RESIDENCE OF ALEXANDER S. COCHRAN, EAST VIEW, N. Y. ROBERT W. GARDNER, ARCHITECT; B. A. HOWES, JR., ENGINEER.

organization. It is, indeed, fortunate that this condition can last but little longer. The technical schools are turning out young engineers well trained in the principles of concrete construction, and several large manufacturers are putting on the market types of unit reinforcement that eliminate much of the necessity for technical engineering ability on the part of the contractor. With these aids and the stimulus of a constantly increasing public demand, one after another of the progressive firms of house-building contractors will enter this field.

The signs point to a time which may dawn to-morrow, when some far-sighted business man and benefactor of the concrete

industry and humanity will, backed by an efficient manufacturing organization, place on the market a standardized reinforcing system, and a reinforcement hand book that will do for concrete what the Carnegie Company and the Carnegie hand book have done for standardized steel construction.

Reinforced concrete has been enthusiastically called a plastic building material. This is only partly true. Its initial plasticity and the widely differing properties of its two component elements, steel and concrete, the one of great tensile and

FIG. 2.—REINFORCED CONCRETE RESIDENCE OF MR. WAITLAND F. GRIGGS AT ARDSLEY-ON-HUDSON, N. Y. ROBERT W. GARDNER, ARCHITECT; B. A. HOWES, JR., ENGINEER.

the other of great compressive strength, have given to the designer a far wider scope than he has ever enjoyed in any other building material. This scope has, however, very sharply defined limitations, and he who solves successfully the problem of concrete design, be his method that of the drafting board, or better, of the modeling table, must have an absolute knowledge of the engineering limitations and necessities of the material with which he is dealing, if his work is to be possessed of any real engineering character and architectural beauty.

No branch of art owes more to the past than architecture. It is only natural that the architects of to-day, who are, as a

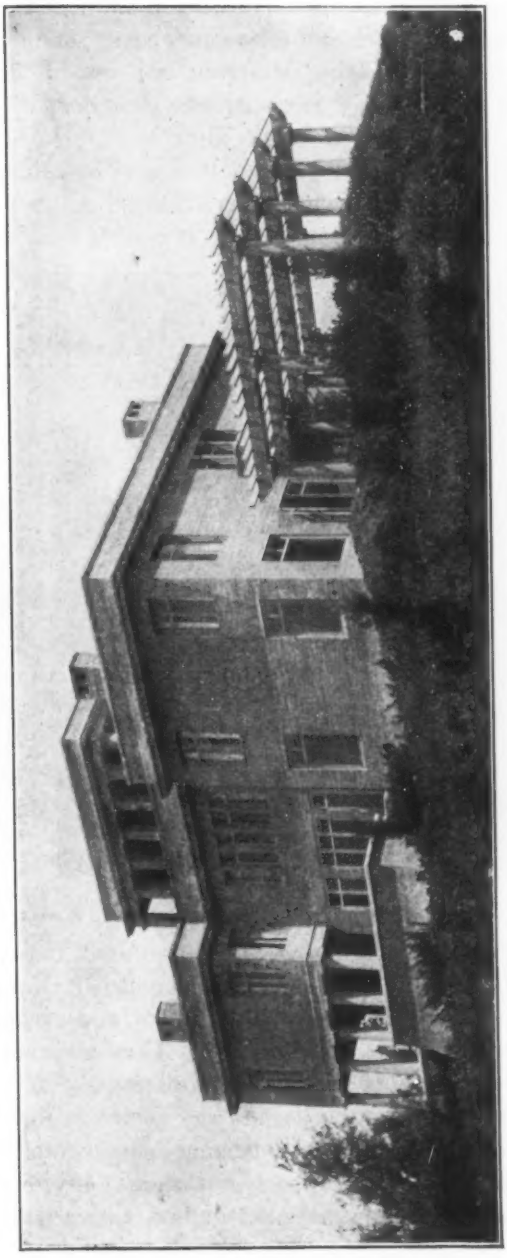


FIG. 3.—REINFORCED CONCRETE RESIDENCE OF MR. SUMMER B. PEARMAIN, FRAMINGHAM, MASS. DESIGNED BY MRS. PEARMAIN; R. A. HOWES, JR., ENGINEER.

class, worshipers of the marvelous beauties that their craft has left to mark the glories of by-gone days, should be slow in adopting the new building material, one that in its nature requires the breaking away from ancient precedent and design and the originating of a new architectural type.

The bolder spirits in the profession, who see the opportunity of great artistic and financial reward in the solution of the

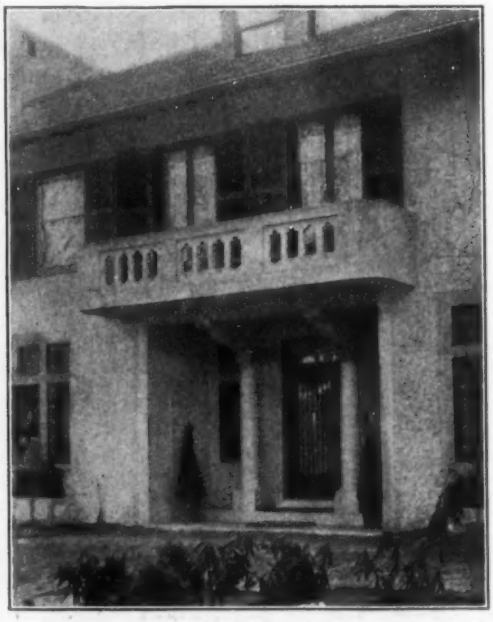


FIG. 5.—LOGGIA ON HOUSE OF MR. GRIGGS.

problem of artistic concrete construction will, of course, have to stand the derisive criticism with which conservatism has always attempted to check development. Thus a recent anonymous architectural writer expresses disapproval of a bridge recently built in the New York Parkway system. In line with the usual criticism of concrete as lacking monumental massiveness, the bridge, he says, in comparison with masonry or concrete unreinforced is "unduly thinned and unduly flattened by means

of the concealed reinforcement," and as for some attendant retaining walls, he says they are "mere inexpressive, expensive expanses of smooth smears!"

Of course there is less mass in a reinforced concrete bridge than in a masonry or plain concrete bridge. And he who criticises the graceful sweeping lines of a concrete bridge does so only because he lacks an intelligent conception of the beauty of architectural expression. Unlike structural steel, the steel of reinforced concrete is not concealed, and is not meant to be. The steel and concrete together make a homogeneous building

FIG. 6.—ENTRANCE FRONT, PEARMAIN HOUSE.

material either element of which is indispensable; and to the seeing eye, well designed works in reinforced concrete always show the steel and to a large extent even the amount of steel used in the reinforcement. The architectural design which fully satisfies the engineering demands of the material and *expresses them to the eye* will be felt in the end to possess true beauty.

Just what style will be evolved as a proper and fitting expression for reinforced concrete only time will tell. One thing we may be certain of, no imitation of stone masonry will be tolerated by the architectural profession, to say nothing of the

public at large. In my opinion the future of concrete architecture lies where that of all other types has lain, in the logical development of the engineering possibilities of a material modified only by conditions of labor. The magnificent supplies of marble, for instance, at the disposal of the Greeks, could be utilized as they were, only by the presence of many highly skilled artisans in a community where the general level of intelligence was remarkably high. The Romans, with less stone and marble, but quantities of high grade natural cement, and a vast amount of unskilled labor in the persons of slaves, were

FIG. 7.—GARAGE AND STABLE WITH LIVING QUARTERS—PEARMAIN HOUSE.

able to construct such a marvel of concrete as the dome of the Pantheon, with its 142-foot span; while their arch construction was a direct expression of their need to use smaller stones than had the Greeks and Egyptians with their great beams and lintels. And it is, of course, well known to you that the direct occasion of the development of the Romanesque recessed arch and the Gothic pointed arch, was the need of still further economy in the use of still smaller stones, and in roofing larger free spaces. It was, so to speak, in silence and darkness, at the call of imperious necessity, that those seeds grandiose architecture germinated. And it is to me at least, of direct and

striking interest that in the same way, in unconscious response to imperious needs, that the first steps have been taken toward that concrete architecture which the architects of to-day will

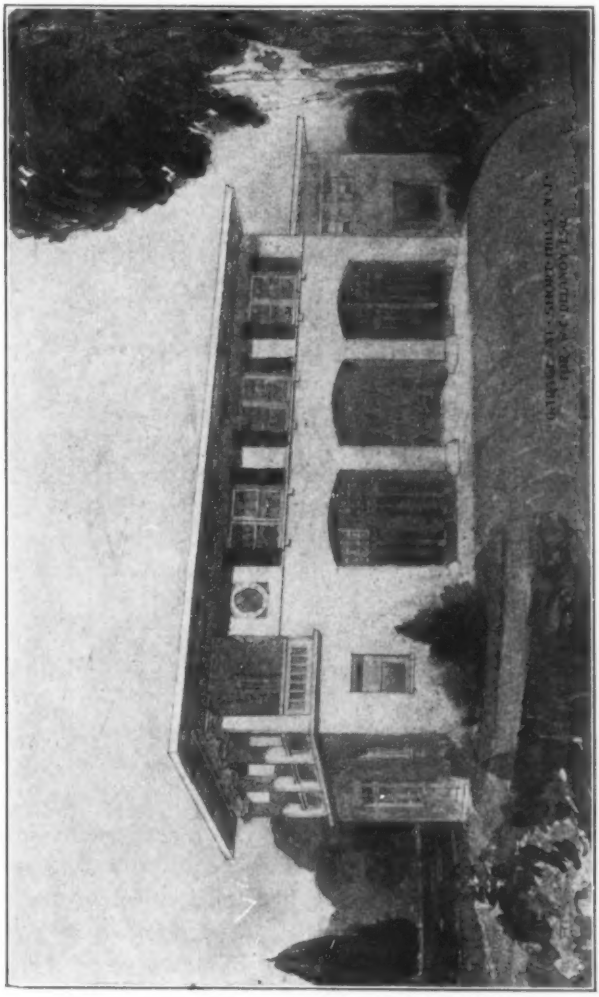


FIG. 8.—DESIGN FOR GARAGE—DE LANOY HOUSE. JOHN A. GURD, ARCHITECT.

carry to a triumphant expression. It is in factory and warehouse construction, the work of those blind utilitarians, the building engineers, that you will find them.

Take the typical case of the transition from beam and column to the flat arch. The typical factory construction in concrete has, up to the present time, been almost entirely of the trabeated or vertical column and horizontal girder construction. The reason for this lies not in the fact that it is the truly economic engineering design in the securing of the maximum amount of efficiency of a given quantity of material, but because the problem of constructing forms in which curves are embodied in an economical manner has not so far been successfully met. But in many of the most advanced examples of factory construc-

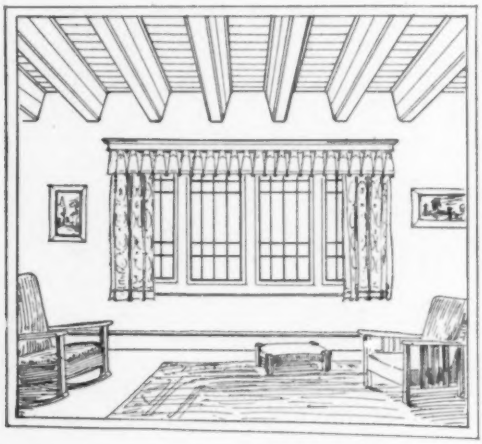


FIG. 9.—SKETCH OF TAPERING BEAM CONSTRUCTION—RESIDENCE OF HINSDALE SMITH, ESQ., SOUTH HADLEY, MASS. KIRKHAM & PARLETT, ARCHITECTS.

tion will be found the bracket, and later, the bracket going over into the flattened arch, simply because it is the strongest shape for a given amount of concrete and steel, meeting the shearing stress and lessening the weight. The point of weakness in a concrete girder is not as is generally supposed at its center; that is its greatest point of strength. The weakness is at the so-called shearing point where the beam joins the column. It is to increase the strength of the beam at this point that the bracket is utilized. Expressed in another way, the flat concrete girder contains a considerable quantity of waste material at its

center that serves no other purpose than extra fireproofing of the steel reinforcing.

The flattened arch will always be the economic type of concrete construction for the reason that the increased cost of concrete offsets the saving of reinforcement when a certain point of spring is reached, on one hand, and the increase of rein-

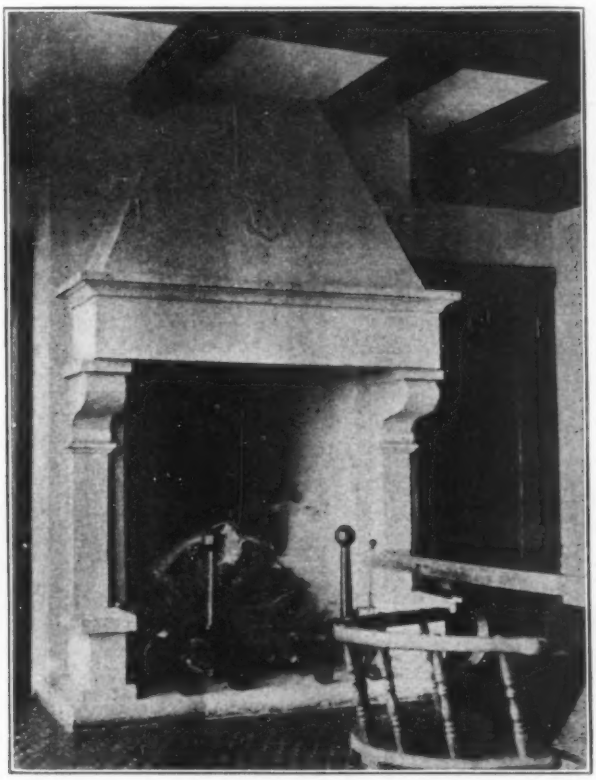


FIG. 10.—HEAVY BEAMS IN DINING ROOM—PEARMAIN HOUSE.

forcement offsets the saving in concrete when a certain point of flatness is reached on the other hand.

As there are two factors to be considered in the economic design of a concrete structure, their comparative cost at the point of construction must be considered before the economic

design can be selected. In the Pittsburg district, for example, steel is cheap and labor and concrete aggregates are comparatively expensive, the cost being approximately $35 a ton for the steel and $12 a yard for the concrete. With these factors the spring of the truly economic arch, eliminating for the time being the question of the forms, would be very slight. Taking, on the other hand, a district in the South, for example, where unskilled labor and concrete aggregates might be obtained at a very low cost, where steel would be excessively high, the factors might

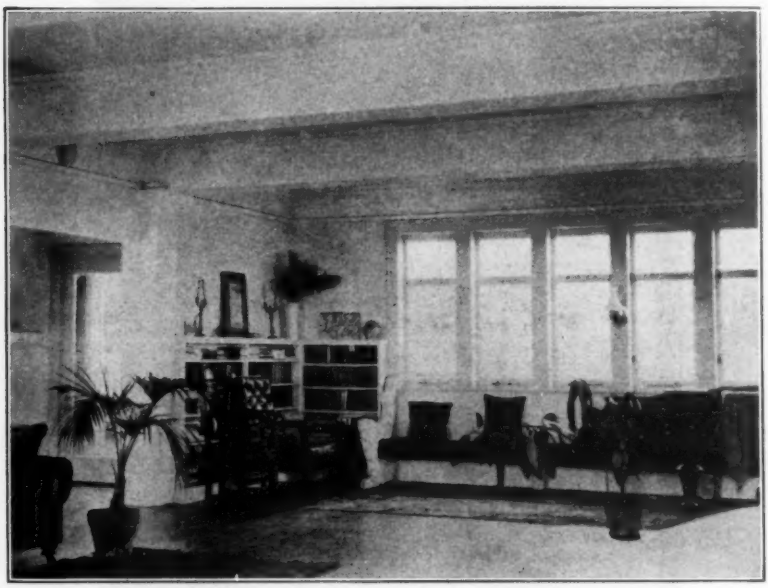


FIG. 11.—HEAVY RECTANGULAR BEAMS—PEARMAIN HOUSE.

be worked out on a basis for $50 a ton for steel and $8 a yard for concrete. In this case, the spring of the arch would be considerably greater. To-day any building of reinforced concrete of the least monumental importance, will be a composition in which the flat arch will be a dominant motive and the truth of this is attested by the recent continental buildings in reinforced concrete.

Now this development in direct response to practical demands, has many parallels, the beginnings of which are to be

found in the same way. But as my subject is not concrete architecture in general, but concrete houses, let me pass on to the variations from the usual type which economy and engineering demand for the construction of dwellings.

First of all, it may be said, that good design in concrete demands broad flat surfaces, in which the artistic effects will be

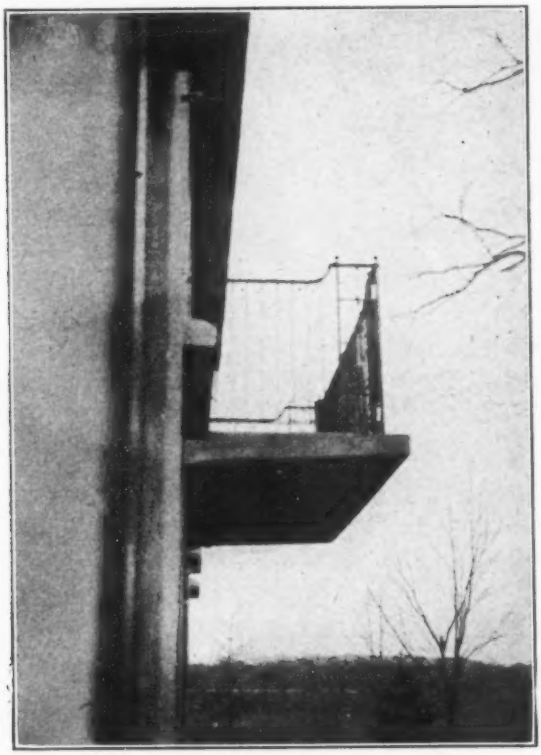


FIG. 12.—BALCONY—COCHRAN HOUSE.

reached by variations in color, and texture, contrasts in texture, or light and shadow from recessed panels, etc. Several typical reinforced concrete houses are shown in Figs. 1, 2, 3 and 4.* In these designs no attempt whatever has been made to imitate cut stone work, but the comeliness of the structural lines themselves,

*For subject of Fig. 4 see colored insert opposite p. 166.—ED.

or contrasts in texture, as about the entrance and windows (Fig. 5) serve to express the material.

This, however, is a point somewhat familiar. What I have heard little of is the value of the flat roof in concrete design.

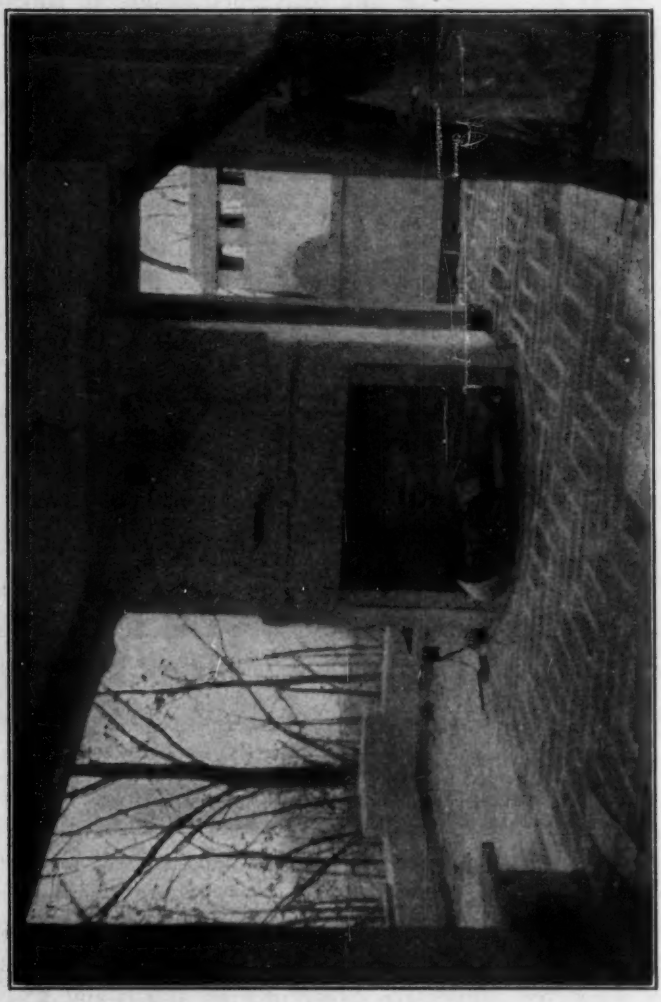


FIG. 13.—ROOF LOGGIA WITH FIREPLACE—DE LANOY HOUSE.

It is the logical construction for concrete, and enables many other valuable properties to be of use. Its economy is attested by the fact that all factory and office buildings and most city

houses have flat roofs. In concrete it is cheaper to build wall than roof (unless roof is nearly flat) and such designs as shown in Figs. 6, 7 and 8 indicate how much extra space is thus given.

It is tradition alone which impels us to cling to the attic and storage spaces of the pitched roof; because we as a nation have been rural dwellers whose families have required the storehouse room. With the change to more highly organized conditions, we need less attic space.

FIG. 14.—GARAGE UNDER KITCHEN WITH SUNKEN ENTRANCE—GRIGGS HOUSE.

Another important development which took its first rise in warehouse construction and which so far as I know has been used for a house only in one case, is the tapering beam, shown in Fig 9. This, of course, is a point of economy, as it omits concrete at the point where it is not needed. I, myself, was astounded at the results of my first experiment in the effect of lightness and spaciousness in a room so treated. Contrast these with the heavy effects of beam in Figs. 10 and 11.

Closely allied with the motive of the flat roof is the new opportunity in the treatment of balconies. The cantilever principle is easily operative here and many suggestions will come to architects from the possibility of a balcony like Fig. 12 or Fig. 5.

In the direction of variations made possible by the fire-proof properties of concrete there is a wide range. The open roof

FIG. 15.—FIREPLACE SHOWING LINTEL OF ROUGH CONCRETE—GRIGGS HOUSE.

loggia, or veranda, with fireplace, is one delightful and very practical possibility. (Fig. 13.)

The garage under the kitchen is another apparently daring but perfectly safe departure. (Fig. 14.)

The treatment of the fireplace itself is till a moot point. Such simple fireplaces as this, in Fig. 15, where contrasts in texture express the nature of concrete, are thoroughly fitting. This fireplace (Fig. 16), in which original sculpture in cement done in place by a well-known sculptor, gives the other extreme of

delicacy. Cut stone ornaments can, of course, be duplicated in cement by ingenious methods, but it would seem that a true æsthetic feeling would seek rather to follow the genius of the

FIG. 16.—FIREPLACE—PEARMAIN HOUSE. SCULPTURE EXECUTED IN PLACE BY L. O. LAURIE.

material in avoiding complicated undercut designs, and choosing bold simple forms or bas-relief. Such modeling as appears in the fireplace and the design for seat and table (Fig. 17), adopted from one of Alma Tadema's pictures, both by a well-known

sculptor, Mr. Laurie, are examples of the healthy use of this plastic but massive material. So also this variation of the Doric columns for a pergola. Notice that the columns are not fluted,

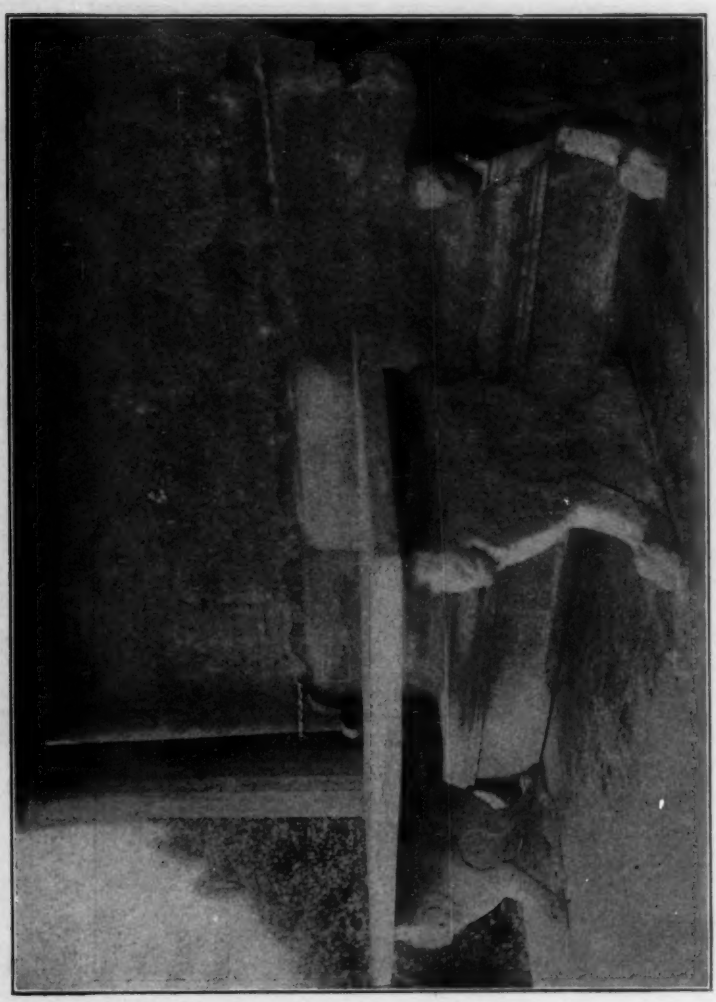


FIG. 17.—CONCRETE SEAT AND TABLE—PEARMAIN HOUSE.

but flat-sided, and on close inspection in no wise an imitation; while yet giving the delicate play of light and shade of the true fluted Doric column. (Fig. 18.)

This brings us to the question of surface ornament in colored mosaic or tile. I have in the past been an opponent of the use of colored mosaic for outside ornament; rather advocating the use of light and shade through offsetting columns and showing arches, recessed panels, etc., but study has convinced me of

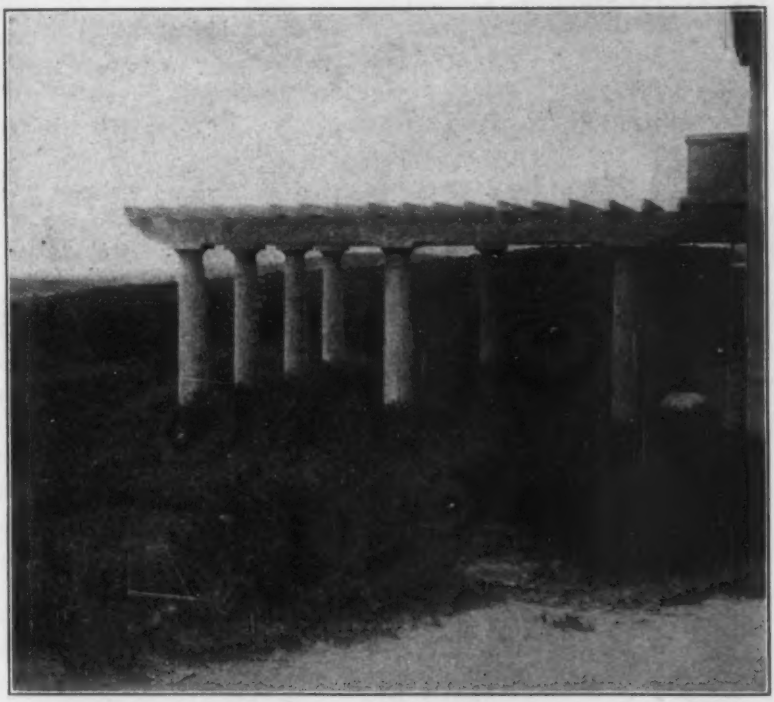


FIG 18.—PERGOLA—PEARMAIN HOUSE. FLAT ENDED DORIC COLUMNS OF REINFORCED CONCRETE.

the great sanitary value, especially for city buildings, of the use of flat ornament flush with the wall surface; and the recent development in mosaic brickwork, in city building especially, has opened up a line of possibilities not even suggested by other work.

In country-house work the window grouping and the texture are the important problems. The grouping of windows, relieving and accenting them by leaded side-lights, or by treat-

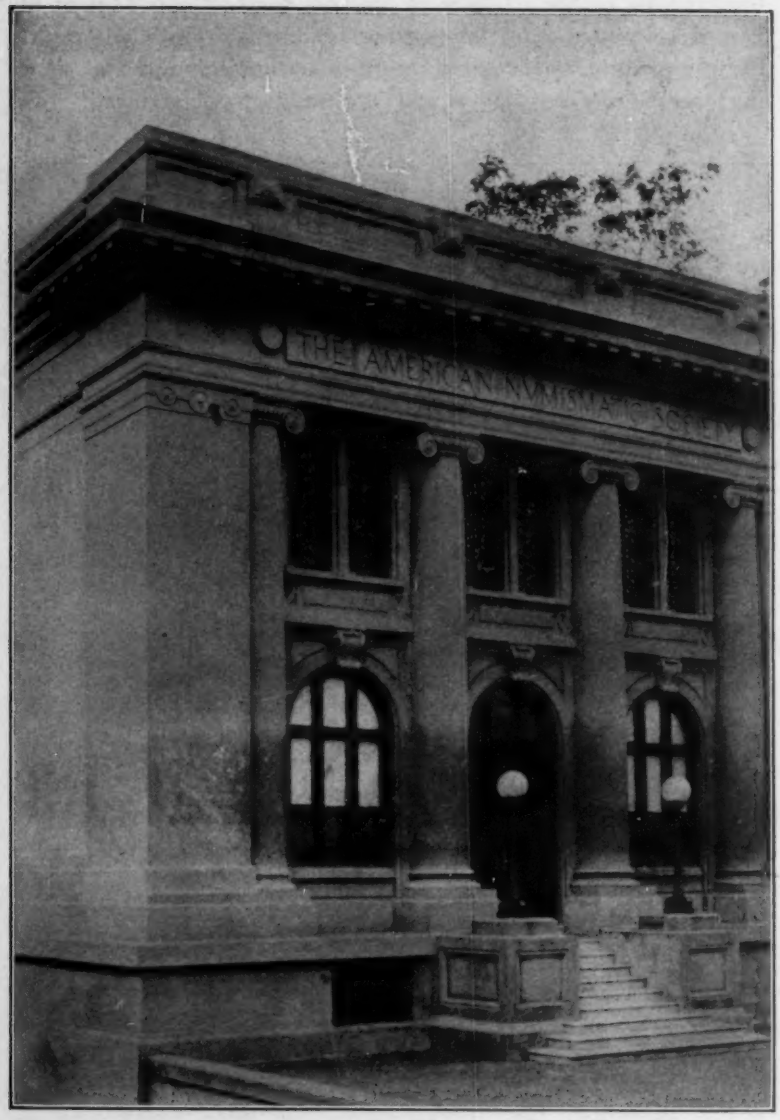


FIG. 19.—REINFORCED CONCRETE BUILDING OF THE AMERICAN NUMISMATIC SOCIETY, NEW YORK, N. Y. NOTE THE EXCELLENT SURFACE TEXTURE. CHARLES P. HUNTINGTON, ARCHITECT; B. A. HOWES, JR., ENGINEER.

ing the surface about them to modify texture, or the construction of sills, lintels and jambs in brick, for example, form a striking and pleasing change from the monotony of an all concrete surface.

Of more prosaic nature are the details of cement floors and bases and metal sash. In public buildings to-day, some combination of cement floors is universal from sanitary and economical reasons. For houses, it is not a matter of adopting them blindly, but with discrimination; experience has shown that they are not more chilling than wooden floors and with white cement and sand as basis, they can be finished to pleasing shades. In order of cost they are (1) plain gray cement, (2) white cement, (3) tinted cement, (4) terrazzo (marble clips in cement polished to bring out the marble) and various forms of floor tile, marble and ceramic.

As for metal sash, in many cases casement sash are desirable for all reasons, and their appearance and reliability justify the slightly increased cost of the excellent metal sash now on the market.

Finally, in regard to texture, there are many methods of reaching interesting and pleasing results, one at least of which has been successfully worked out by Mr. Albert Moyer, in the construction of his home. A volume could be written on these methods, but as they are being eagerly and successfully studied at present (Fig. 19), I will turn rather for my last word to the province in which I as an engineer now feel most keenly the need of the interest and progressive achievement of the architectural profession.

It is in the realm of *characteristic* reinforced concrete design that the work is loudly called for—design of the house, and especially the small house, that shall not imitate wood work, or brick work, or stone work, half timber or stucco, but shall clearly express the qualities of this noble building material, its monolithic quality, its capacity for enormous spans, its economic curves. Here the first suggestions are ready to hand—it is for the young architectural genius to make the most of them.

THE CONSTRUCTION AND COST OF SMALL CONCRETE HOUSES.

By C. R. KNAPP.*

The use of concrete for small and medium-priced dwellings, stables and garages presents a vast field for operation. In my opinion it is one of the largest in the cement world.

The construction of large concrete buildings in nearly every city has been an object lesson to the people. It has given them much food for thought and, as thought begets investigation, they are fast putting two and two together and arriving at the conclusion that what is good for the hard-headed man of large finances, who has had scientific and expert advice, must be good for them. Fortunately they are not confronted with a proposition involving the intricate engineering problems of large structures. There is, however, one point to be made clear, and that is the cost. This, to the masses means much. In talking with people about concrete, invariably the first question always is—"How does concrete construction compare as to cost with other building materials?" In answering this question let us take up an analysis of the cost of the different materials and see just where concrete construction really stands.

Stone, or stone backed with brick, is admittedly much higher in cost than other materials. If the stone is quarried on the lot near building site, the cost will be somewhat lessened, but will be still higher than brick.

Frame construction has not the same standards of cost as other materials. We cannot, therefore, give reliable data. For example, one contractor offers to build a house for $2,000; another, the same house for $2,500, and a third contractor will ask $3,000. What do you get? Simply what you pay for, no more no less. The first house is merely thrown together, good only for from three to five years, and is then apparently an old

*C. R. Knapp and Company, Philadelphia, Pa.

house, its value having depreciated fully 30 per cent. to 50 per cent. It will always be in need of repairs. The second house, of better construction, is good for from ten to fifteen years, with repairs beginning after the third or fourth year. From then on repairs are an ever increasing, fixed yearly expense. The third contractor, for $3,000, has constructed a good frame house, that will last from twenty-five to thirty-five years. To do this, however, the frame has cost more than concrete. The cost of the other two houses is less than concrete, but in from five to eight years, the cost is much more and the difference increasing every year. In addition, there is a depreciation for wear and tear, whereas, the concrete house, like good wine, improves with age.

Brick construction will cost for a 13-inch wall, 36 to 50 cents per square foot of wall, and a 9-inch wall will cost from 25 to 35 cents per square foot of wall. To these figures must be added, for the finished wall, cost of furring, lathing and two brown or scratch coats of plaster and the white coat.

Hollow tile construction, which has an advantage over brick by reason of its air space, averages about the cost of brick or a trifle under. In comparing it with concrete, the writer knows of a case in point, where an owner thought the concrete bids were too high and turned to the tile, expecting that the cost with this material would be much lower, as he had been led to believe. The unexpected happened. The hollow tile bids were higher, thus showing that it costs more than concrete.

Concrete blocks, at a less cost, have all the good points of the hollow tile construction and a few more besides. There is nothing better than a concrete block wall, where the blocks are properly made, cured and placed. The difficulty with ninety per cent. of the block houses about which there has been complaint, is generally found upon investigation to be defects in the laying up. The public does not know this and at once condemns all concrete blocks as bad, when even a poor block will give a fairly good result, if the mason will only do his work right.

The cost of block construction is from 18 cents to 35 cents per square foot of wall having a thickness of eight to twelve inches inclusive. For the finished wall, add the cost of the white finish coat which is put directly on the concrete, thus saving the

cost of furring, lathing and the two brown or scratch coats of plaster. Blocks are condemned by many, because the outward appearance does not appeal to them. Architects say that the rock face is a bad imitation and inartistic. Admitted, but 90 per cent. of the people who use them choose this surface. It is also claimed that, as the blocks are so regular in size, it gives the building a look of sameness. This can also be said of brick.

All of these arguments can be met by making a block of coarse materials with a very rough surface and by laying them up without pointing the joints. Then rough casting the wall to any surface desired. A rough stucco or pebble dash wall is always acceptable to the architect. By this method, you have not only completely changed the appearance, but you have done this without losing even one of its good features and at a less cost. I believe this method to be the cheapest in the block business.

A plain or reinforced concrete wall is much stronger in every feature than a brick wall. It is, therefore, not necessary to make the concrete wall as thick, in order to get the proper factor of safety. The Philadelphia building laws take cognizance of this fact by requiring in concrete only two-thirds of the thickness called for in brick.

For house construction, I would advise two four-inch walls, with a four-inch air space. The two walls should be tied with metal ties in concrete webs. This gives a wall of full strength, saves materials, gives an absolutely damp-proof house, and all the benefits derived from the four-inch air space. It also saves the furring, lathing and two brown coats of plaster, the finishing coat being plastered on the concrete. This wall will cost from 15 to 25 cents per square foot of wall, plus the finish coat.

Another method is to use a six-inch wall, which is strong enough for any two-story house, with furring, lathing or metal sheathing on the inside, which gives enough air space to keep any dampness from coming through. Plaster in the regular way with two brown coats and one finish coat. This will cost from 11 to 18 cents per square foot for the concrete, plus the furring, lathing and plaster. These prices are equal to six to ten dollars per cubic yard for concrete.

Concrete partitions, two inches thick,—reliable in every way,—nothing better—can be put up for 16 to 20 cents per square

foot. Floors, by using concrete in connection with hollow tile, can be placed for about 25 to 40 per cent. more than the wooden joist construction we are now using.

A concrete roof costs but a few dollars in excess of what we are paying for the best wooden shingles. After we have these things, we have a structure which does not require any painting, repairs or outlay of any kind. We have a fireproof house which does not depreciate, but rather increases in value. It saves the large insurance expense, and fuel. It is a delight to the owner, because it is cool in summer and warm in winter.

To reduce the cost of construction of the small reinforced concrete building, a method must be applied that is at once simple, quick, practical and economical. The system which is economical for the large structure is too high in cost for the small structure. During the past summer the writer constructed a stable for Mr. Robert E. Griffiths, at Haverford, Pa. The outer walls and partition walls were six inches thick. They were all carried up at the same time as a unit. To do this, we used two rounds of 12-inch boards inside and out, fastened with the Dietrich clamps. The result obtained was quick construction, which means a saving of labor, economical use of lumber and a minimum cost which was in this case, $1,580, as compared with a bid for brick of over $2,500, and for frame of $2,000. The lumber used for forms and scaffolding was all utilized in the carpenter work, thus there was no waste.

Where the form is a part of the builder's permanent equipment, to be taken from job to job, I would suggest units eight feet long by three feet wide. When two rounds of 12-inch board units are used it often happens that the placing of concrete is delayed owing to the men changing forms and not being able to keep ahead of the mixing. By using two rounds of the 8-ft. x 3-ft. units, which are easy to handle and cost no more to place than the one-board units, two men changing forms can keep ahead of six men mixing and placing. This gives the concrete a longer time to set before the forms are taken off.

If care is taken in placing the concrete there are no surface voids and it will leave a smooth wall for any of the many different finishing methods we may wish to apply.

The method giving the best result for the least work is by thoroughly wetting the walls and then applying with a brush a thin 1 - 2 mortar, rubbed in well with a carborundum stone. This produces a lather on the surface, removes all board marks and fills the pores. Before dry go over the wall with a brush dipped in water. The result is a hard, smooth, even surface and uniform in color. A green wall can be done in the same way.

In conclusion I would like to refer to the problem of satisfactory treatment of concrete houses from the architect's point of view. The leading architectural magazine in this country recently sent out a circular in which the following statement appeared:

> There is no reason in the world why even the suburban residence or farmhouse should be a hodgepodge of irrelevant architectural details, enclosing a sorry assortment of poor and, therefore, uneconomical construction and equipment. The sad, costly, architectural aberrations which line even the main thoroughfares of our leading cities are the gratuitous insults of ignorance. Nobody means offence, nobody wilfully chooses the poorer result, but it is not to be avoided when the worse appears the better reason. We need a united effort for reformation. We need to establish a fair average of critical judgment. We do not need an artistic police, but we need an artistic school for art.

We, as cement users, can derive great satisfaction in knowing that the condition of affairs as described by this high authority in the domain of architecture, cannot be charged to builders of concrete houses, as the latter are so much in the minority that the criticism quoted could not apply to them. But it brings up something for future consideration along the line recently suggested in the editorial columns of one of the leading New York engineering journals. In urging that we substitute fireproof construction for the dangerous and combustible materials usually found in dwellings of moderate cost, the editor stated that the objection to concrete might, after all, be due to the fact that we have not become familiar with it, rather than to any intrinsic fault in the material itself. It is my conviction that the people will learn to admire and come to like the plain and simple concrete house, just as they have learned to appreciate many other plain and useful things that former generations regarded as incomplete unless profusely carved and ornamented.

To illustrate my meaning, the modern steel railway coach with its cement floor might serve as an example as opposed to the highly varnished and over ornate style of car that preceded it. We find the trend of critical taste already pronounced in this direction, and it will not be long before public taste will follow, with concrete affording unexampled opportunity to exemplify it in attractive and indestructible dwellings of moderate cost.

THE IMPORTANCE AND COST OF CEMENT TESTING.

By W. Purves Taylor.*

Although the importance of testing is generally recognized by the large consumers of cement, especially those engaged in constructing public works, its value, even to the present time, is not always apparent to the consumer of smaller quantities. It must be remembered that cement is an artificial product made by mixing certain ingredients and then treating the mixture in a complex mechanical process, so that even if the greatest care is exercised as it is in the best plants, certain variations in quality must necessarily exist. The ingredients are not by any means constant in composition, and hence both the proportions of the mixture and the treatment of manufacture must be continually changing. It is accordingly unreasonable to expect that any cement should invariably be uniform in its qualities and properties. The older plants have a certain advantage of experience over the newer ones, but, even in these occasional batches of inferior cement are produced and allowed to get on the market. In the writer's laboratory all the well-known eastern brands of cement are constantly being tested, and no one of them has escaped occasional rejections.

Reliable manufacturers generally take every precaution to prevent defective cement from leaving the mill, and make most careful tests to that end, but these tests are subject first to possible laboratory errors of sampling and manipulation and secondly do not and cannot take into account the alteration in its properties that the cement undergoes under certain conditions after leaving the mill. These variations and irregularities in the cement unavoidable in manufacture and not always discovered by mill tests, and which may be vital to the integrity of the finished structure, show the importance and the necessity for cement testing.

*Engineer in charge, Testing Laboratory, City Hall, Philadelphia, Pa.

It is often argued that while testing is necessary for larger engineering works it is not as necessary for the smaller consumers—those erecting small buildings, making concrete blocks, or laying sidewalks—while, as a matter of fact, it is especially important in these cases, for if there is any particular difference in the quality of the material at the mill, it may be taken for granted that the poorer cement will be sold where it will not be tested. Even the cement rejected on the large works is generally sold to a dealer or small consumer. The trouble and cost of testing may at first make it seem almost prohibitive, but after a user of cement has begun testing and has found the freedom it gives from trouble on the work, and has felt the assurance that all his structures are safe and permanent, he realizes its value and invariably continues it.

The fact that poor concrete may be made from the best cement by reason of the use of an indifferent quality of aggregate or by careless mixing and placing, is no argument against testing cement, but rather one for it, because careful inspection during construction will readily detect and correct these conditions but no field inspection can prevent the use of inferior cement. A user of cement who desires the best quality of materials must therefore depend upon laboratory tests.

At the present time, however, it is almost unnecessary to advocate cement testing, for its importance has become so generally recognized that all important works regard it as an essential accompaniment to concrete work. The vast amount of cement now used requiring tests and the ensuing competition for decreased cost in testing has led however to an unfortunate condition in the testing itself.

Cement testing is a difficult process requiring experience, care, precision, and knowledge, and hence should only be entrusted to well qualified men, but too often this important work is relegated to utterly untrained and careless operators and the results obtained by such methods are really worse than nothing as they often are positively misleading. Many tests made at the present time by supposedly responsible parties are ridiculous in their inaccuracy, as any one having knowledge of this subject will admit. Instances might be cited without num-

ber. In one case a cement was rejected as being quick setting, but an investigation showed that the test had been made in a hot room in a temperature of over 80 degrees and the specimen besides placed directly over a radiator—the cement itself was entirely normal. Strength tests are often made by inexperienced boys committing every possible error of manipulation. In one case a cement reported as breaking at 125 pounds was found to give a strength of over 250 pounds when accurately tested. Cases of unjust rejection on the accelerated test for soundness through improper manipulation and interpretation of the results are by no means uncommon. Of the sieves used for testing fineness, not one in four has been properly standardized. These inaccuracies, it must be remembered, are not only found in the small laboratories but only too often in those of some reputation, and the cause may be found to be entirely due to the desire to cheapen the cost.

It should be recognized at once that if cement tests are made it is worth while to make them well, even at possibly a somewhat increased expense. A properly made cement test complete is worth to any commercial laboratory from eight to ten dollars a sample, with chemical testing at from a dollar and a half to two dollars per ingredient extra. Accurate appliances, experienced trained operators, and intelligent oversight can not be used if the cost is materially less, unless under exceptional conditions, and, without this accuracy in the work, tests have but little value. When a large laboratory is installed directly on the site of construction, testing many samples a day, with no charge for collecting the samples, and running at no profit, it may be possible to test cement for as low as from 1 to 2 cents a barrel, but for the ordinary concrete jobs it cannot be expected to cost much less than 4 or 5 cents a barrel.

To save time, trouble and some expense, it has become a frequent practice to test cement at the mill as it is packed in the cars. This is convenient as it does away with the trouble of sampling on the work and with the delay of waiting for the test, since the seven-day tests may often be completed before the car arrives on the work. In spite of this convenience, however, the practice is not to be recommended on account of the

alteration in its properties that the cement may undergo in the interval. This applies particularly to the time of setting. A cement may leave the mill slow-setting and arrive on the work very quick-setting, due to temperature or atmospheric conditions. Even the strength may be altered considerably. Hence to be reliable the tests should be made only after the shipment is received on the work, even if more trouble is involved thereby. If an established brand is being used, I would place much more reliance upon a 1-day test made on the work than upon a seven-day test made on a sample taken at the mill. If mill tests are used, however, check tests for time of setting should always be made on the work.

Although the common period for tests is seven days, it is often permissible to use a familiar brand on a one-day test, for if all the other properties are similar to those commonly found it may generally be assumed that the seven-day strength will also be similar. A three-day sand test is often a convenient guide for the early acceptance of a shipment.

The tests that give the best indication of the quality of a shipment are soundness, sand-strength, setting, fineness and percentage of sulphuric acid. Neat strength and specific gravity have generally but little value as acceptance requirements. Of these tests all can be completed in 30 hours from sampling except the seven-day strength. If a three-day sand test is used in addition, little if any delay will be necessary while waiting for tests.

In conclusion—well made tests of cement are of the greatest importance and value to every consumer of cement, but they must be made with the greatest care and only by responsible and trained men. If so made, the tests are well worth the time and trouble they cost. A cheaply made test, however, is liable to prove an expensive investment.

THE AVAILABILITY OF CONCRETE FOR BRIDGES: ITS COST AND DURABILITY.

By Henry H. Quimby, M. Am. Soc. C. E.*

Concrete—either plain or reinforced—as a material for bridge construction possesses the merit of being adaptable as a substitute, within limits, for both stone masonry and steel framework, and of combining the qualities of both. It is equal to and may be more economical than stone masonry for abutments, piers, retaining walls, coping, and parapets, and in many cases makes an arch available with its manifold advantages where a stone or brick arch would be impracticable.

It is found also to be an advantageous substitute in the shape of jack arches or reinforced slabs for steel floor troughs and buckled floor plates on steel bridges, whereby we have a composite structure—not strictly reinforced concrete, but a combination of steel members and concrete members. The resulting product when the design and workmanship are good, is a rigid, enduring and economical bridge.

The limitations of the proper and economical employment of concrete in bridge structures can hardly be stated, certainly not with any degree of definiteness. Conservative designers are not in entire accord with respect to either methods of use or allowable working stresses, and comparisons of value and cost between all steel and part or all concrete or reinforced concrete can only be made on finished designs and for the same site. Even then estimators may not agree as to which will cost the most, and, if we may judge by the wide range of prices quoted in contractors' proposals, the contractors themselves cannot more accurately determine relative values in cost. To the engineer or purchaser the cost of a bridge is the contract price—the cost to the builder should of course be less. The actual cost of a job to the

* Engineer of Bridges, Philadelphia, Pa.

builder is usually not published and is rarely divulged to even the engineer, and the latter's basis of estimate must be the bids and contract prices previously obtained.

Any list of costs will exhibit great variation in the figures for structures of the same class and similar dimensions and conditions, and when the almost infinite variety of conditions and combinations of varieties are considered, the difficulty of conveying useful intelligence on the subject is apparent. The length of span, width, height, depth and character of foundations, length and shape of wings, loads to be carried, amount of filling or grading, railing or parapet, character and amount of paving, plain or decorative architecture, character of the concrete—plain, reinforced or rubble, market price of materials, and accessibility of the work to railroad service, all affect the question of cost.

It is therefore impracticable to select any unit of measure of a bridge and use it as a reliable basis for estimating cost. In a table covering eighteen concrete bridges recently built in Philadelphia the concrete price spread upon the span area—the clear span by the width—varies from $3.11 to $9.74 per sq. ft., and it varies from $1.73 to $7.39 per sq. ft. of area occupied by the ground plan to ends of wings, the latter extremes being not on the same bridges as the other two. The average of the lot was $6.25 per sq. ft. of span area and $3.50 per sq. ft. over all, most of them being single span bridges with long wings, and all being highway bridges designed to carry loads of forty tons on two axles 20 ft. apart. All have ornamental concrete balustrades and washed granolithic surfaces, and paved decks, with electrical conduits and manholes, and water-pipe and sewer well-holes, and some have pretty deep foundations.

If the whole contract price be set against the yardage of the concrete in the structure the unit costs vary from $8.50 to $11.25 per cu. yd. averaging $9.75.

It is found that in the circumstances under which the bridges referred to were built steel plate girder bridges will cost more than concrete arches, the difference being considerable. Several opportunities for fair comparison have made this clear, as great a difference as 25 per cent. of the higher being indicated. This saving is in the first cost, and if we add the capitalized cost of

proper maintenance of the steel structure—which seems to be a fair element in the comparison—the advantage of the concrete arch appears far greater. A real money value also attaches to the superior beauty and attractiveness of a decorative arch structure in almost any locality—a question that almost always is the subject of consideration and decision in designing public work, for it must be determined what amount is proper to be expended for mere appearance.

The composite bridges—steel structural frame with concrete envelope—share with the arches or at least promise to—the quality of permanence, and therefore, exemption from expensive maintenance charges. As between the ordinary steel plate

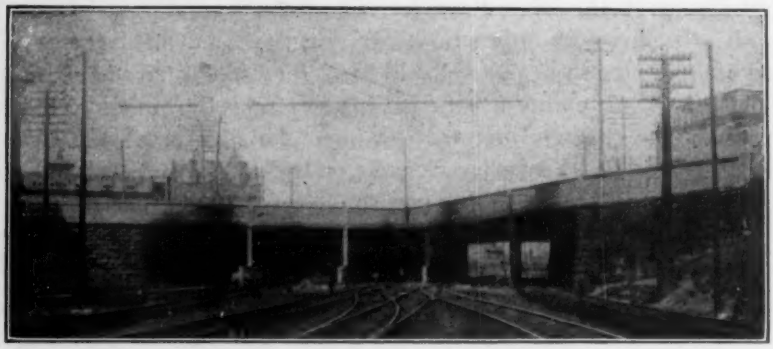


FIG. I.—BRIDGE OVER PENNSYLVANIA RAILROAD, BELMONT AND GIRARD AVENUES, PHILADELPHIA, PA. STEEL COLUMNS, GIRDERS AND FLOOR MEMBERS ENCASED IN CONCRETE.

girder bridge with buckled plate floor for permanent paving, and the composite type, the lower first cost is with the composite if the spans be short, for the greater dead weight of the concrete floor tells on the long main girders whose section is usually determined by the general load—dead plus distributed live—while the individual floor members are determined by the heavy concentrated live load. The embedment of the floor stringers or joists in the concrete jack-arch construction effects a saving of steel, first by dispensing with floor plates, and second by permitting lighter stringers to be used, for the jack-arches distribute a concentrated load over say three beams where with a buckled

plate floor each beam must carry the whole concentration, and, besides, the embedment of a beam in concrete increases its carrying capacity about one-third. Fig. 1 shows a bridge of this type.

Where it is the practice to protect steel over railroad locomotive service by means of a wooden ceiling under the whole underside of the bridge the economy of the concrete floor is more marked because such a ceiling costs about 25 cts. per sq. ft. and lasts only a few years. This first cost alone will pay for about one cubic foot of concrete in the floor, and only about 15 to 18 ins. average thickness of floor concrete is required. As steel floor

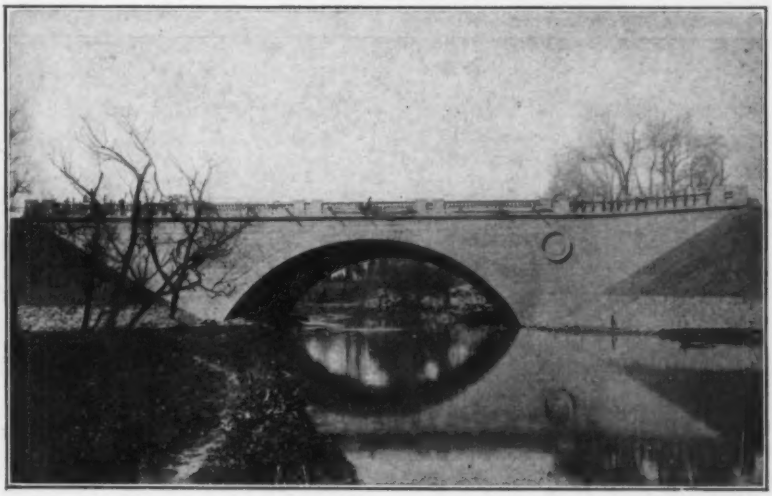


FIG. 2.—BRIDGE OVER FRANKFORD CREEK AT WYOMING AVENUE, PHILADELPHIA, PA. 90 FT. CLEAR SPAN. RUBBLE CONCRETE THROUGHOUT, NOT REINFORCED. CONCRETE BALUSTRADE.

plates with their riveting cost from 50 to 70 cts. per sq. ft. the concrete floor appears to cost only about one-half as much as an all steel floor, besides saving materially in the stringers. Floor-beams may or may not be required heavier to carry the concrete floor. If they are not very long the value of the concrete embedment may make up for the increased dead load stress. The main girders will need to be heavier than for the steel floor because little or no value can safely be assumed to be derived from the concrete casing.

The cost of concrete bridge work of almost all classes can be materially reduced and the service value of the concrete at the same time increased by the embedment in the concrete of suitable hard stone in size from that of spalls to the largest that can be conveniently handled or that will be comfortably accommodated in the compass of the forms. The economy of this construction depends upon the cost and shape of the embedded stone and the amount embedded without too much labor expended and without restricting the output of the concrete plant. It has been found that the percentage of the volume of the finished work that such stone amounts to varies from 25 to 40, or from 33 to 66 per cent.

FIG. 3.—BRIDGE AT ROCKLAND STREET OVER NORTH PENN RAILROAD, PHILADELPHIA, PA. 60 FT. CLEAR SPAN; RUBBLE CONCRETE ABUTMENTS, WALLS AND BALUSTRADE. REINFORCED CONCRETE ARCH.

of the volume of the mixer concrete, according to the shape of the stone and the care taken in placing it.

The cost of handling and placing this approximate third is probably about equal to that of mixing and handling and placing an equal volume of concrete. The saving therefore should be the difference between the delivered cost of the concrete materials and that of the stone. If the stone delivered costs one-half as much as the cement and sand and gravel that when mixed equals it in volume, and if the embedded stone amounts to only one-third of the finished work, then the cost per cubic yard of the finished work is 80 per cent. of that of plain concrete.

COSTS OF REINFORCED CONCRETE BRIDGES ESPECIALLY WITH REGARD TO MAINTENANCE.

By E. P. Goodrich, M. Am. Soc. C. E.*

In an informal discussion on the subject of steel-concrete arches and other structures of similar composition, held at the Annual Convention of the American Society of Civil Engineers, June 26, 1906, two almost opposite opinions were expressed with regard to the relative costs of structural steel and of reinforced concrete for bridges.

Mr. R. S. Buck, while acknowledging "his limited experience with the system," in his opening remarks, stated that the development of reinforced concrete work†

> has been largely in the hands of contractors and contracting engineers, with whom a vital point has been to bring it in competition with all-steel construction. In this, the speaker inclines to think, there has been rather an unfortunate disposition to reduce the cost unduly at the sacrifice of certainty, stability and durability. It is not possible to construct a steel-concrete arch that will compare in cost with an all-steel bridge and at the same time furnish the desired characteristics to be reasonably looked for in a masonry arch.
>
> The steel-concrete bridge possesses sufficient merits, the speaker believes, when designed on conservative lines, to often reduce the question of first cost to a minor position; and if it cannot do this it is a good form of bridge to let alone.

The opposite idea was conservatively expressed by Mr. J. R. Worcester, as follows:‡

> One statement by Mr. Buck, if correctly understood, that there could be no comparison between the cost of steel-concrete bridges and steel bridges seems to the speaker to be true only when one factor, that is, the cost of the abutments for the steel bridges, is left out of consideration.
>
> The speaker's experience is, that, in the case of a highway bridge of moderate span, a comparison between a steel-concrete bridge and one of steel with buckle-plate floor filled on top, will show that the steel-concrete bridge is considerably cheaper; and that where good foundations are easily

* Consulting Engineer, New York, N. Y.

† Trans. Am. Soc. C. E., vol. XLVI, p. 95.

‡ Op. cit., p. 101.

obtained, if the total cost of bridge and abutments is included in the comparison, there is a fair chance for steel-concrete construction to compete with all-steel.

Between these two views there is sure to be a middle ground of fact, the boundaries of which may, however, be difficult to define, but after nearly ten years of phenomenal development in concrete construction some added experience has thrown additional light on the subject.

At the quarterly meeting of the Association of American Portland Cement Manufacturers, held in Philadelphia, April 10, 1907, Mr. George S. Webster discussed the subject of "Concrete Bridges." In it he described briefly the Walnut Lane Bridge in Philadelphia. In answer to an inquiry, he said:*

The contract price for the bridge was $262,000. A steel bridge would probably cost less in this location; a stone bridge approximately fifty per cent. more. The additional cost of this bridge over one of steel is due to the cost of centering. As the bridge is located in Fairmount Park and over the picturesque Wissahickon Creek, a steel bridge would be inappropriate with the surroundings.

A MEMBER:

Have you stopped building steel bridges?

MR. WEBSTER:

We have not. The bridge at Girard and Belmont Avenues over the Pennsylvania Railroad is of steel. The outline and shape of it is such and the clearance is so small that it would be difficult to design anything but a steel bridge in that position.

In this case it is to be observed that no real competition took place between those advocating concrete and those who exploit steel bridges. A decision was reached requiring the construction of concrete and the first cost was of rather secondary consideration. And that has come to be the general attitude of those associated with the selection of types of bridges for given sites much more than was the case eight or ten years ago. At that time alternate bids were often asked for steel bridges and also for concrete arch construction. Among many such cases the following may be cited, wherein the reinforced concrete design carried an estimated cheaper first cost:

(*a*) A seven-span bridge of concrete at Waterloo, Iowa, cost $54,000, or $1.80 per sq. ft., while the lowest bid for a plate girder construction was higher.

* Bulletin No. 15, Assoc. Am. Portland Cement Mfrs., p. 11.

(*b*) A seven-span bridge of concrete at Dayton, Ohio, cost $123,170. Eight bids were received for a steel plate girder design and seven on the concrete-steel design. The latter were about $10,000 the lowest.

(*c*) A 120-foot span concrete bridge at Lansing, Mich., cost $31,000, while the lowest of the three steel bids was $35,000.

(*d*) While not strictly a competition, it is to be noted that with regard to the Sandy Hill 15-span concrete bridge, which cost $77,000, Prof. William H. Burr, in a letter to the writer says: "I am very sure that a steel bridge to carry the same loads could not have been built for much, if any, less cost than the reinforced concrete structure."

(*e*) A cheap but substantial highway bridge in Wabash County, Ind., which was guaranteed flood proof, cost $573 in competition with steel bridges and plain concrete culverts of same span and roadway, the lowest bid on steel being $665 and on plain concrete $943.

(*f*) The Illinois Central Railroad erected a bridge over the Big Muddy River for the following approximate amounts:

Work for railroad company	$34,402
Work by contractor	72,128
Skeleton steel	4,451
Crushed stone	7,200
Engineering, etc.	6,700
	$124,881

This may be compared with the cost of enlarging or rebuilding the original piers and abutments and placing thereon a superstructure of three double-track steel spans built to carry the present standard loading, estimated as follows:

Masonry	$30,000
Falsework	10,000
Shop work at 3.58 cents	75,180
Erection and painting	10,500
	$125,680

(*g*) At Yorktown, Ind., was erected a 95-foot span highway bridge for about $100 less than the lowest bid for a steel truss bridge of the same span. The construction was completed and the bridge thrown open for traffic in only a little more than sixty days after the award of the contract.

On the other hand steel often is of less first cost than concrete:

(*a*) In the case of the Junction Hollow Bridge in Schenley Park, Pittsburg, a concrete arch estimated to cost $7 per sq. ft. is described as "only a trifle more than was paid for the steel arch which was accepted and built."

(*b*) At Stockbridge, a small foot bridge over the Housatonic, if built of iron, was estimated to cost $1,475, while the concrete one actually erected cost more than that figure, because of bad foundations.

(*c*) The competitive plans prepared for the Memorial Bridge over the Potomac, for the Chief Engineer of the Army, included several different designs in concrete. It is said that a steel structure for the same site would have cost about 33 per cent. less than that of the winning design in reinforced concrete.

(*d*) In the competition for a bridge at Plainwell, Mich., twenty-three proposals were submitted for different types of steel bridges, varying in price from $14,000 to $26,000; all the leading builders in the country being represented. For concrete-steel construction, six bids were received, ranging from $16,000 to $27,000. The Board favored a concrete bridge, but the only bid within the appropriation ($20,000) was rejected on account of faulty design. At an adjourned letting, three bids were received for concrete-steel, varying from $19,900 to $20,500.

Some other comparisons in first cost may also be instructive:

(*a*) For a bridge over the Neutra at Neuhansel, in Hungary, a concrete bridge consisting of six spans, each 55.8 feet in the clear, cost $13,700, while a wooden one of twelve spans was estimated to cost $12,000.

(*b*) The concrete arch over Park Avenue, in Eden Park, Cincinnati, cost $7,130, while a stone structure was estimated at $12,000.

(*c*) At Belleville, Ill., for a bridge over Richmond Creek, plans were prepared for bridges of iron, stone, brick and concrete. Bids were received on the last two named only and ranged between $11,259 and $12,830 for a brick arch, and between $10,433 and $12,110 for concrete.

(*d*) At Indianapolis, the lowest price received for building two Melan bridges was $105,340, the lowest price for stone bridges being $140,996. Steel bridges, although somewhat lower in cost than the concrete ones, were rejected on account of their inferior beauty and their temporary character.

In an interview with Mr. Edwin Thatcher, the Nestor of concrete bridge builders of the United States, he stated that concrete could almost always compete with steel for highway structures whenever the floor in each case was to be paved like the street surface. When, however, a plank floor was allowed in the case of the steel structures, concrete could not usually compete successfully, simply on the basis of first cost. Concrete has not been used to any great extent in railroad work except for spans so short as to class the structure as a culvert. The Florida East Coast Railway is a case, however, where many miles of concrete arch viaduct were erected and steel structures were not con-

sidered, the writer is told. Other railroads are also taking up this class of construction more and more as time passes and it will doubtless soon be recognized as a special type of construction for inspection and other purposes.

Mr. George P. Carver, in his hand book on Reinforced Concrete, gives detailed estimates of concrete arch bridges of 50, 75 and 100 ft. span, 28 ft. wide, from which he has prepared a curve of costs to be used in roughly estimating such structures for inter-urban railroad use.

The estimates are as follows:

SPAN, 50 FT.; WIDTH, 28 FT.

Steel, 27,700 lbs., at 2½ cents	$692.50	
Steel placing, 27,700 lbs., at 1 cent	277.00	
Formwork at $1 per cu. yd.	370.00	
Cement, 481 bbls., at $2	962.00	
Sand, 185 cu. yds., at $1	185.00	
Stone, 370 cu. yds., at $2	740.00	
Mixing and placing 370 cu. yds. at $1.50	555.00	
	$3,781.50	
Incidentals add 15 per cent.	567.22	
	$4,348.72	
Profit add 10 per cent.	434.87	
		$4,783.59

SPAN, 75 FT.; WIDTH, 28 FT.

Steel, 38,800 lbs., at 2½ cents	$970.00	
Placing steel, 38,800 lbs., at 1 cent	388.00	
Formwork at $1 per cu. yd.	740.00	
Cement, 962 bbls., at $2	1,924.00	
Sand, 370 cu. yds., at $1	370.00	
Stone, 740 cu. yds., at $2	1,480.00	
Mixing and placing 740 cu. yds. at $1.50	1,110.00	
	$6,982.00	
Incidentals add 15 per cent.	1,047.30	
	$8,029.30	
Profit add 10 per cent.	802.93	
		$8,832.23

SPAN, 100 FT.; WIDTH, 28 FT.

Steel, 55,650 lbs., at 2½ cents	$1,391.25	
Placing steel, 55,650 lbs., at 1 cent	556.50	
Formwork at $1 per cu. yd.	1,008.00	
Cement, 1,310 bbls., at $2	2,620.00	
Sand, 504 cu. yds., at $1	504.00	
Stone, 1,008 cu. yds., at $2	2,016.00	
Mixing and placing 1,008 cu. yds. at $1.50	1,512.00	
	$9,607.75	
Incidentals add 15 per cent.	1,441.16	
	$11,048.91	
Profit add 10 per cent.	1,104.89	
		$12,153.80

Table I gives some of the dimensions and costs of a number of arches. In the case of single arch spans, the cost per square foot is computed from face to face of abutments and out to out of railings.

Continental European practice is well described by Prof. Mörsch in "Eisenbetonbau." Translations of the pertinent parts of this book are as follows:

In the early stages of railroad construction, culverts, roofed with natural stone, were extensively employed. With the advent of concrete and of cement pipe, arched conduits, easily constructed in concrete, or for smaller openings, concrete pipes were substituted. With the introduction of reinforced concrete, however, slab culverts again became useful. Since it is possible with the aid of reinforcement to make the concrete slab resist any bending stress, the span of the slab on the clear way through these culverts can be increased to about 6.5 m. (21 ft.), so that their field of usefulness has been greatly extended. The span might be still further increased, but beyond about 5 m. (16 ft.) T-beams are cheaper than simple slabs. . . . The usual arrangement is (then) to span the opening with several similar parallel girders and lay a floor slab between them. . . . T-beam bridges of this type, of spans up to 16 m. (52 ft.), are entirely practicable and in most cases cheaper than steel bridges. Special instances exist of 20 m. (66 ft.) spans. . . . With wider spans, the girders become rather heavy, so that T-beam bridges possess little superiority over steel ones. . . .

An important advantage of such reinforced concrete bridges over railways is that they are not affected by the gases from the locomotives, which, in the case of busy stretches of track, and where difficult of

TABLE I.—DIMENSIONS AND COSTS OF CONCRETE ARCH BRIDGES.

Place.	Over	Total Length Bridge.	Arch Spans.	Width.	Rise of Arch.	Total Cost.	Cost per sq. ft.	Date Erected.
Pine Road, Philadelphia.	Pennypack Creek	.....	2a 25′4¾″	34′3½″	6′6″	$8,662	$4.94	1893
Neuhansel, Hungary.	Neutra	.....	6a 55′9½″	19′8″	3′8½″	13,700	2.00	1893
Munderkinger, Wurtemburg.	Danube.....	.....	164′0″	26′3″	16′5″	21,420	4.50	1894
Richmond Ave., Syracuse.	Harbor Brook.	.....	12′0″	49′0″	2′6″	2,000	3.40	1894
Eden Park, Cincinnati.	Park Ave. ..	.....	70′0″	32′0″	10′0″	7,130	3.15	1895
Stockbridge.....	Housatonic..	.....	100′0″	7′6″	10′0″	1,475	2.00	1895
Belleville, Ill. ...	Richmond Creek.	.....	40′0″	52′0″	7′0″	10,500	3.90	1895
Topeka.....	Kansas River.	693′0″	5a 125′0″ 2a 110′0″ 2a 97′6″	40′0″	.....	125,000	4.50	1896
Inzigkofen	Danube.....	.....	141′0″	12′0″	14′4″	6,650	3.70	1896
Immau	Eyach.....	.....	98′5″	13′1″	9′10″	4,285	3.30	1898
Green and Goat Islands.	Niagara.....	371′0″ 198′0″	2a 103′6″ 1a 110′0″ 2a 50′6″ 1a 55′0″	40′0″	.....	102,070	4.50	1900
Indianapolis....	Fall Creek...	.....	6a 74′0″	65′0″	9′6″	105,340	3.70	1900
Juana Diaz, Porto Rico.	Jacaguas River.	404′0″	1a 120′0″ 2a 100′0″	18′0″	12′0″ 11′3″	59,438	8.15	1900
Juana Diaz, Porto Rico.	Guayo River.	270′0″	3a 70′0″	.....	7′6″ 7′0″	25,683	5.25	1900
Worthington ...	Piney Branch	.....	24′0″	26′0″	5′0″	3,170	5.10	1900
.....	Quarry Road.	.....	80′0″	28′6″	14′0″	21,500	9.40	1900
Chatellerault, France.	Vienne.....	443′0″	164′0″	26′3″	15′0″	35,000	3.00	1901
Washington.....	Rock Creek..	.....	80′0″	27′0″	15′0″	17,500	8.10	1901
Wabash Co., Ind.	.....	.....	25′0″	16′0″	.....	573	1.45	1902
Forest Park, St. Louis.	River des Peres.	.....	45′0″	45′0″	.....	10,000	5.20	1902
Liabach, Austria.	Liabach.....	.....	109′4″	50′0″	14′4″	30,000	5.60	1901
I. C. R. R.	Big Muddy River.	483′0″	3a 140′0″	34′2″	30′0″	125,000	7.60	1901
Plainwell, Mich.	Kalamazoo River.	446′0″	7a 54′0″	25′0″	8′0″	19,900	1.80	—03 1903
Saley St., Brooklyn.	Prospect Ave.	125′0″	85′0″	60′0″	.....	21,800	4.30	19—
Munich	Grunwald ...	720′0″	2a 230′0″	30′0″	42′0″	65,000	3.10	1904
Connecticut Ave. Washington.	.....	1,341′0″	2a 82′0″ 5a 150′0″	52′0″	41′0″ 75′0″	850,000	12.20	1905
16th St., Washington.	Piney Branch	272′0″	125′0″	25′0″	30′0″	42,731	6.25	1905
Dayton	Great Miami..	588′0″	69′0″ to 88′0″	56′0″	.....	123,170	3.70	1904
Park Ave., Newark.	Branch Brook Park.	243′7″	132′0″	74′0″	10′2″	84,000	4.70	1905
Connington, Viaduct.	.....	600′0″	10a 50′0″	16′0″	16′0″	52,200	5.43	1903
Greensburg, Ind.	Clifty Creek..	.....	80′0″	16′0″	12′0″	2,695	2.10	.....
Wayne St., Peru	Wabash Rvr.	500′0″	6a 75′ to 100′	30′0″	15′0″	36,900	2.46	.....
Wabash, Ind....	Charley Crk..	.....	2a 75′0″	30′0″	18′0″	7,000	1.56	.....
Pollaskey	.....	800′0″	10a 75′0″	18′0″	11′0″	48,000	3.33	.....
Meridian St.....	.....	250′0″	3a 74′0″	60′0″	9′0″	51,000	2.26	.....
E. Washington St. Indianapolis.	.....	.....	65′0″	57′0″	10′0″	10,885	2.94	.....
Muncie, Ind. ...	.....	.....	38′0″	16′0″	7′6″	640	1.21	.....
Bangor, Me.	.....	90′0″	46′7¾″ 38′2″	40′0″	8′7″ 7′6″	6,500	1.80	.....
Mieres, Spain ...	.....	333′0″	3a 34′4″ 2a 114′4″	23′ app.	.....	30,300	3.90	.....
Skodsbury, Denmark.	.....	.....	71′6″	10′0″	.....	2,000	2.80	.....
Sandy Hill	.....	1,025′0″	15a 60′0″	35′8″	.....	72,000	2.00	.....
Walnut Lane, Philadelphia.	.....	585′0″	233′0″	60′0″	.....	262,000	7.50	.....
Emperor Bridge, Sarajeno.	.....	.....	115′10″	40′0″	12′0″	16,500	12.00	.....
Maryborough, Queensland.	.....	613′0″	a 80′0″	22′8″	4′0″	75,000	5.40	.....
Lansing, Mich...	Grand River..	.....	120′0″	52′10″	23′0″	31,000	4.90	.....

access, cause active corrosion and high maintenance charges for steel structures. . . . If the length of a horizontal reinforced concrete bridge is greater than 16 to 20 m. (43 to 66 ft.) intermediate supports must be provided. . . .

In straight girder bridges of greater lengths an expansion joint must be provided about every fourth opening. . . .

In arched bridges, reinforced concrete can be employed either for the arch alone, or the superstructure, including the roadway, or in all structural parts. . . .

In medium spans, of 40 to 50 m. (130 to 165 ft.), the employment of reinforced concrete as the arch material is less frequent, since, in this case, provided a proper profile has been employed, no tensile stresses occur because of the large dead load. On the other hand, reinforced concrete is better adapted for long spans. If the safe compressive stress in the arch is not to be exceeded, it is necessary to limit the weight of the superstructure, and this can be done by a suitable employment of reinforced concrete. In this way the dead load stresses will be greatly reduced, but the small edge stress may decrease to zero or change to tension under unfavorable live loads, so that the reinforcement is again necessary.

In consequence, where it is desired in small and medium spans that no tensile stresses shall exist, or in other words, where only mass concrete work is employed, the superstructure cannot be kept too light. A light superstructure is then justifiable only when demanded for architectural reasons or when it is necessary to impose as little weight as possible on the foundations. . . .

The arches can be constructed as restrained or as three-hinged by using suitable material. . . .

A large number of examples are given of each type of construction mentioned. Among them are included the three-hinged arch in Grunwold over the Isar. It is 220 m. (772 ft.) long, including two main spans of 70 m. (230 ft.), with a rise of 12.8 m. (42 ft.). The floor has a width of 8 m. (26.2 ft.) between rails. Prof. Mörsch (who was also the designer) finally remarks:

Since the actual cost of the bridge was only about 260,000 m. ($62,000 approximately), it is demonstrated, as far as the Grunwold-Isar bridge is concerned, that arched bridges with a proper arrangement of reinforced concrete and of large span, can compete successfully with steel construction.

In this connection it should be noted that such published lump costs as appear from time to time in the technical magazines, should not necessarily be interpreted as the actual construction costs of the work, unless the contractor is known to be one of long experience in bridge erection. The governing bodies of

municipalities, counties, companies, etc., are altogether too prone to accept the lowest bid in a competition, irrespective of the qualifications of the bidder. Many inexperienced men have submitted figures on work which they were unable to compass, when put to the actual test, often losing heavily but being compelled for business reasons to shoulder the loss and say nothing. In other and rarer cases, the work has suffered to a dangerous degree and the municipality or other body for which the bridge was erected has lost much more through costs of repairs, than the difference between the lowest actual and the lowest responsible bid. Such bodies will usually save money in the long run by retaining the services of one of the several expert concrete engineers now to be found in this country, who will either prepare a single design upon which all bidders can base their figures, or prepare specifications calling for detailed designs accompanying each bid, with the privilege retained of accepting any bid which is considered as best meeting the requirements of the case. A waiver should also be exacted of each bidder, concerning any claim whatsoever for himself or any other if his bid is not accepted.

All the costs contained in Table I are first costs, or the initial expenditure, which is almost invariably financed by an issue of bonds by the municipality, township, or corporation undertaking the erection of the structure. These bonds usually carry about four per cent. interest and run for a period of from twenty to fifty years, provision for their retirement being made by the establishment of a sinking fund in which is placed a small yearly percentage raised by taxation or derived from income. The gross amount of these two annual obligations thus usually amounts to between six and ten per cent. of the cost of the structure. This condition is the same, irrespective of its type, the only point being the reduction of this yearly expenditure to a minimum by cutting down the first cost as much as possible and extending the life of the bonds as much as advisable so as to reduce the annual amortization charge. Obviously, the bond period should not extend over a greater period than the life of the structure.

The question then immediately arises as to the probable relative and actual lives of various types of bridges. Stone arch

bridges have been in existence from the times of antiquity, but the advocates of steel structures will say "they were not built of concrete." In the south of France is a concrete arch bridge known as the Pont du Gard which was erected in the year 56 B. C. The concrete in this was not composed of crushed stone or other small aggregate of the variety now employed in concrete bridge work, but was of the old style, consisting of alternate layers of large and small stones, gravel, etc., and of cementitious materials. Vitruvius describes the materials and methods in use before the Christian era and other writers like Alberti in 1485 and Polladio in 1570 accurately describe the method which "the ancients" (as they call them) employed, "of using boards laid on edge and filling the space between with cement and all sorts of small and large stones mingled together." It is very improbable that the Pont du Gard would have withstood the vigours of climate of the Northern United States, but its actual state of preservation, as well as that of many other specimens of ancient concrete work, proves that if modern work is honestly executed, it will many times outlast any reasonable bond period, so that a very small yearly sinking fund per cent. is all that is required for properly designed and erected concrete work.

Fr. von Emperger, M. Ans. Soc. E. and S., in a paper read before the American Society of Civil Engineers in April, 1894, writes as follows:

> It is not out of place to remember that quite a number of concrete structures, in addition to the Roman water conduits, have stood through centuries; as, for instance, the cross-arched vaulting (78 ft. span) over the bath of Diocletian, in "Hexædra amplissima," and the parabolic main aisle of St. Peter's (87 ft. span and 150 ft. rise), both in Rome.
>
> Speaking of modern structures, the writer may mention the bridge over the Isere, France (span, 85 ft.; rise, 8.5 ft., and 2.5 ft. thickness in crown); the bridges over the Saevale and the Iregua near Torio, Spain (spans, 33 ft.; rise, 7.5 ft., and 3 ft. thickness in crown), and the aqueduct at Vannes, France, built in 1868-69. . . .
>
> In the latter the arches have 75 and 125 ft. span. Later on, the Pont d'Alma and Pont Napoleon were built as railway viaducts near Paris, spans about 140 ft. and one-tenth rise. Another more recent example (1873) is a bridge of 105 ft. span, 13 ft. rise and 20 in. thickness at the apex, near Erlach, Germany.

In the photograph of the Aqueduct of Vejus reproduced in that paper, the characteristic appearance of concrete is visible at many points.

To steel or wooden structures, on the other hand, only a relatively short life can be assigned at best. Wood will be dismissed without further comment, except to remark that, in some parts of the West where wood is exceedingly cheap and where steel and cement can be obtained only after being transported very long distances, so that their costs are very high (from the heavy freight rates made necessary), it may be possible that wooden structures involve the smallest yearly charge, in spite of their very short life, even when treated with creosote or other preservatives.

Turning to steel then as the only real competitor of concrete, a remark ascribed to the late George S. Morrison is often repeated, that

> Steel bridges are built to last fifty years, but they do usually last hardly half that time.

This condition is due to insufficient or entire absence of maintenance. The writer has been told of one highway bridge in Wisconsin which had to be replaced after only eight years of service. Of course this is an exceptional case. Steel bridges over railroad tracks where locomotive gases can produce their full destructive effect, have been known to last just about the same period. Mörsch cites an example of a girder erected in 1886 and found with its web entirely eaten away at many points, in 1907.

In a paper read by Prof. C. M. Spoffard and Mr. F. H. Fay, Dec. 16, 1908, before the Boston Society of Civil Engineers, the Boylston street bridge over the Boston and Albany Railroad tracks in Boston is described and its history recounted. It was originally erected in 1888, with small clearance between the floor system and the locomotive stacks. It was subject to almost constant train service, and except for the top chords, was practically built anew in 1908. In the new structure, all floor beams, etc., were protected with concrete, while the bottom chords were raised above the level of the floor planking, which thus protects them.

Where highway bridges are properly maintained, even when subjected to the action of locomotive gases, they have been known to last much nearer the theoretical limit assigned them by Mr. Morrison than this one last cited. On the New York Central

Railroad are several which were erected as long ago as 1868, 1874, 1875, 1875, 1876, 1876, 1877, 1884, 1884, etc. These figures in each case give the actual dates of erection of special structures. The great total, and almost steady yearly, increase in weight in railroad rolling stock during the past twenty years has made it necessary for practically all of the older roads to rebuild and strengthened their track structures, so that little real information is obtainable as to the possible life of a steel bridge. With careful inspection and maintenance there is really no reason why a well-constructed steel bridge should not last indefinitely, and such structures as Brooklyn Bridge (built in 1884, for example), or the Niagara Arches, may be expected to see many generations.

In the *Technograph* of the University of Illinois, for 1893, Mr. Albert F. Robinson, Engineer of Bridges and Buildings of the C., R. I. & P. Ry., states the principle that the life of steel railroad bridges is only fifteen years because they must all be rebuilt to accommodate heavier traffic at intervals of about that length. Mr. G. W. Kittredge, Chief Engineer of the New York Central system, stated to the writer that they had practically rebuilt all the bridges on their system during the past few years commencing in 1900, but that while those in the list mentioned above had largely been strengthened, the old portions were still in excellent condition. He stated further, that when the Grand Central Station train shed was removed this year, it was found in remarkably perfect condition. It was erected in 1870, of wrought iron imported from England. The Cincinnati and Southern Railway was built about 1880, and the bridges along its line were constructed in an especially substantial manner and in accordance with specifications which were then considered as particularly advanced. Nevertheless, about 1900 it became absolutely essential to rebuild them and the past five years has seen a gradual reconstruction throughout the whole system. Again in this instance the twenty-year interval is apparent as the maximum period for special bridge bonds, if they were to be issued.

A conservative deduction from the above mentioned, and many other observations, would lead to the conclusion that ordinary highway bridges should not be assigned an average life ex-

ceeding twenty years at most, and fifteen would be a really better period to which to limit the life of steel highway bridge bonds. Railroad bridges usually receive better care, and their life may be considered as somewhat longer, except that from time to time they must be strengthened in order to make them safe for increased loads.

Mr. Robinson, in the paper cited above, presents estimates of the costs of strengthening single track structures of different lengths, assumed to have been erected about 1882 in accordance with the standard specifications of the Erie Railroad, issued about 1879, and so rebuilt as to conform to the standard specifications of the Lehigh Valley Railroad, prepared in 1892. In condensed form they are as follows:

Length in Feet.	Cost in 1882.	Cost of Strengthening in 1897.	Per cent.
40	$901.10	$377.27	41.4
50	1,344.20	580.50	43.0
60	1,816.20	713.50	39.25
80	3,036.20	1,408.15	46.0
100	4,539.00	1,925.50	42.0
120	6,018.00	2,857.30	47.0
140	7,792.28	3,573.90	46.0
160	9,929.70	4,388.35	44.0
180	11,679.00	5,158.50	44.0

These figures reveal the average percentage of cost of renewal to be 43.6. This is in addition to the regular maintenance costs and is equivalent to about 3 per cent. per annum, corresponding to a life of about thirty-five years for the original structure, computed on this purely theoretical basis.

In discussing this subject it is very difficult to separate the annual depreciation from the maintenance costs. Lumping all such items together, the New York Central assumes five per cent. per annum as the amount on which to base all maintenance and depreciation charges when contracting with municipalities concerning railroad and highway crossing structures. Since this figure is to cover all charges of whatsoever kind, it is necessary to assign somewhat more than this figure or about thirty years as the assumed life of the bridge and thus a somewhat arbitrary but fairly satisfactory rate of depreciation can be assumed for all

steel bridges. On this basis, at least five per cent. should always be assumed as the yearly amortization rate for such structures, against not to exceed 2 per cent., corresponding with a bond period of fifty years, for concrete ones, irrespective of first cost.

Turning now to the subject of maintenance, pure and simple, nothing has yet been written better than the Preliminary Report of the Committee on Iron and Steel Structures of the American Railway Engineering and Maintenance of Way Association, contained in Bulletin No. 81, an extract from which is as follows:

The maintenance of a metal bridge consists in the prevention of deterioration by rust and wear, the repairing of all damage resulting from internal or external causes, and the necessary strengthening of the structure if called upon to carry loads heavier than those for which it was designed.

To attain these ends the structure must be kept free from rust by proper cleaning and painting, motion between the various parts must be reduced to a minimum, expansion joints must be kept working freely, all defects and injuries must be promptly discovered and repaired and its capacity determined as accurately as possible.

The purpose of an inspection are to ascertain the condition and safety of the structure and to determine the amount and rate of deterioration and the necessity for repairs or renewal. Ordinarily a thorough annual inspection made by a competent inspector will suffice for most cases where the bridge is properly constructed and is not overloaded. On the other hand, nothing short of a daily inspection will be sufficient to discover with sufficient promptness the damage caused by an accidental blow.

Between these two extremes there are many reasons for making inspections of more or less thoroughness and frequency.

The following scheme for inspection seems to be an average of the practice of the various roads replying to the circular. It is applicable to either the divisional or departmental system of maintenance:

(1) By trackmen daily in connection with the inspection of the track, to note especially whether the structure has suffered any damage from drift, high water, slides or objects falling from cars and any movement of the substructure.

(2) Monthly by a member of a bridge gang reporting through the foreman to the Supervisor of Bridges and Buildings, to ascertain condition and safety of structure and repairs necessary.

(3) Annually by an inspector, to obtain a detailed report of the condition of the structure for office record and to determine the amount of deterioration, safety and necessity for repairs or renewals.

(4) Annually by the authorities having charge of the structure, to determine the necessity for extensive repairs or reinforcement or renewals.

In addition to the foregoing, special examination should be made as occasion may require as follows:

(*a*) Of structures that are strained high or show signs of distress under traffic.

(*b*) Of substructures showing signs of movement until it has been ascertained that a state of stable equilibrium has been reached, or until movement becomes so great that rebuilding is necessary.

(*c*) After heavy freights for evidence of damage to superstructure by drift and to substructure by scour.

(*d*) By Engineering Department whenever a structure is reported as requiring repairs or renewals.

The items which are to be noted by the inspector, as required by the Oregon Short Line Railroad, are as follows:

1. Class of structure.
2. Length.
3. Opening of spans.
4. Height to base of rail.
5. Approaches.
6. Ties.
7. Rails.
8. Spike.
9. Guard rails.
10. Stringers, attachments.
11. Corbels.
12. Caps, sills, timber walls.
13. Posts or piles.
14. Sway braces.
15. Waterway.
16. Culvert pipe.
17. Box culverts.
18. Paving.
19. Bench and end walls.
20. Ring or covering stone.
21. Piers and abutments.
22. Pedestal blocks.
23. Bed plates.
24. Anchor bolts.
25. Line camber.
26. Tension members.
27. Compression members.
28. Floor beams, attachments.
29. Lateral connections.
30. Hangers.
31. Long suspenders.
32. Loose pins or nuts.
33. Loose rivets.
34. Drain holes.
35. Vibration.
36. Deflection.
37. Painting.
38. Wall plates.
39. Bolsters.
40. Angle blocks.
41. Bottom chord joints.
42. Chord bolts.
43. Clamps and packing.
44. Gib plates.
45. Covering.
46. Water barrels.
47. Ladders.

This list is somewhat more detailed than are those of many other roads, but the number of items mentioned only shows the more clearly the necessity for constant and rigid inspection of such structures and the many points from which trouble may arise.

For comparison with the foregoing, herewith is submitted a somewhat similar list of items concerning concrete or stone arch bridges.

1. Class of structures.
2. Length.
3. Openings or spans.
4. Height to base of rail.
5. Approaches.
6. Ties.
7. Rails.
8. Spikes.
9. Guard rails.
10. Waterway.
11. Paving.
12. Soffets.
13. Spandrels.
14. Abutments.
15. Wing walls.
16. Piers.
17. Parapets.
18. Drain holes.
19. Expansion joints.
20. Vibration and deflection.

The points to be noted are almost entirely cracks; their location, width, length, depth and water bearing qualities. Their location will determine to a certain extent whether they are due to settlement or spreading of abutments, to setting, shrinkage, changes of temperature, or overloading. Their change of size with variation in load, humidity, temperature, etc., will afford further information, especially as to their cause and cure. The amount of water coming through them and its quality is of importance in determining the dangerousness of their existence from another point of view.

In properly reinforced concrete, failure is sure to be very gradual so that there is less chance for accident than in some other types of structure, nevertheless, it is wise to inspect them just as frequently as is done on other varieties of bridges. Their foundations should be given especial care in original design, in construction, and in periodical inspection after completion, because there is almost invariably a smaller waterway left in the design of arch bridges, than in the case of the vertical abutments for a steel bridge. Worse scouring, especially in time of flood, may thus be produced and inspectors should note all phenomena along this line. On the whole, therefore, no saving can be made in the costs of inspection by the erection of concrete structures in place of steel, and hence this small but important item can be ignored in making a comparison.

One of the best known reinforced concrete construction companies gives the following reasons for the choice of concrete structures in place of steel:

STEEL BRIDGE.

Labor	All come from out of town.
Steel	
Material	
When built the bridge is	Unsightly.
	Costly to maintain in roadway and paint.
	Constantly in need of inspection.
	Short lived.
	With wooden floor in danger of burning.
	Subject to rust in hidden parts.
	Noisy under traffic.

In general use only because up to the introduction of the reinforced concrete arch it was the only fairly durable low-priced bridge.

REINFORCED CONCRETE BRIDGE.

Most of the carpenter and other labor is hired in the town.

Gravel	Money for all these goes into the business of the town.
Sand	
Stone	
Cement	
Lumber	
Teaming	
Board	
When the bridge is built	It increases in strength as it grows older.
	It is the most graceful bridge made.
	There is no maintenance expense.
	It is quiet under traffic.

When maintenance of a steel bridge is considered, a reinforced concrete bridge shows economy of investment.

It is the last claim in which the present interest centers and by the foregoing presentation, the only points now left open for comparison are costs of roadway renewal and of repainting. The former is a most difficult matter for determination since a concrete structure will always carry the regular railroad ballast and track, or the highway or street surfacing, which has to be

maintained only to the same extent as the adjoining thoroughfare. It has already been stated that concrete cannot usually compete with steel highway bridges (as to first cost), when the latter are to be designed with plank flooring. The life of this material is extremely variable, depending almost entirely on the density of traffic. On Brooklyn Bridge the 2½ inch spruce plank of the wearing surface must be replaced about every four months, while the writer has known of country highway bridges in which the flooring rotted away so as to need renewal before the traffic had produced enough wear to necessitate relaying. Between these two extremes the conditions are so wide as to make this item too indefinite to be entertained except in cases or locations where the wear and cost of renewal are known. In such an instance it is only necessary to estimate the yearly expense for renewal and compute from it the percentage of the total cost of the structure. As an example, assume a bridge 100 feet long and 30 feet wide of which the planking has to be renewed once a year. Assume a three inch yellow pine wearing surface which costs, including tearing up, spikes, labor, material and supervision, forty dollars a thousand. This item then aggregates, $30 \times 100 \times 3 \div 1000 \times 40 = \$360$. If the initial total cost of the structure were $10,000, the yearly percentage cost of roadway renewal would be slightly less than four. This figure is known to be very modest and when it (which represents a yearly cost of 12 cents per square foot in this instance) is compared with $1.35 per square foot, which is about the yearly cost of renewal of the planking of the Brooklyn Bridge, this point is made all the clearer.

The floors of railroad bridges (unless constructed with buckle plates or similar material, on which the regular ballast road bed is carried), are largely of timber which has a relatively short life. In general it may be estimated that the wooden portion of such a floor will last about ten years in the northern part of the United States, decreasing to about six in the Southern States. The cost of a floor is almost purely a function of the length of the bridge alone, so that it is impossible to assign to it a percentage value. A rough estimating figure of $3.00 per foot per track is sometimes given for the timber work. The following table gives some estimated costs of steel work and

railroad bridge floors for different spans, for the sake of comparison:

Span in Feet	Type.	Cost per foot of Span.		Total.	Per cent cost of renewal of timber work per year.
		Steel.	Floor System.		
45	Pl. Girder	$25.00	$3.00	$28.00	1.1
60	Pl. Girder	30.00	3.00	33.00	0.9
85	Pl. Girder	39.00	3.00	42.00	0.7
100	Pony lattice	38.00	6.00	44.00	0.7
100	Lattice	29.00	10.00	39.00	0.8
125	Lattice	35.00	10.00	45.00	0.7
150	Pin	36.00	12.00	48.00	0.6
175	Pin	41.00	12.00	53.00	0.6
200	Pin	46.00	12.00	58.00	0.5
250	Pin	60.00	12.00	72.00	0.4

The painting of a steel structure is a great question. There are several hundred "best paints" on the market, some of which are good, and some of which will hardly last until the paint salesman can collect his bill. The best paints obtainable will last about six years, after which period a new painting is necessary for good maintenance. The claims of some manufacturers greatly exceed this period.

The Bridge Department of New York makes a practice of painting Brooklyn Bridge about once in three years with one good coat at a cost of about $20,000. This, of course, affords an opportunity for a thorough inspection, and, furthermore, this structure should be made to last indefinitely if careful maintenance can do so. The largest contemplated concrete arch (that of the Hendrik Hudson Bridge) has a span of only about 725 feet, while the Brooklyn Bridge center span is 1595 feet, 6 inches, so that using it for comparative purposes is obviously somewhat straining a point. Nevertheless, its cost information is of great interest. In arriving at an annual percentage cost for painting, there is again a certain amount of uncertainty. However, a rough approximation may be arrived at from the usual estimates for steel structures. The total cost of a steel bridge varies widely from year to year, prices for similar work at different times within the writer's experience running from $70 to $105 per ton. Of

this amount, about $2.50 should cover the cost of painting an average railroad bridge, while highway bridges run somewhat higher, due to their relatively lighter structural members.

It is to be noted that the first application costs relatively more for material and less for labor than subsequent ones are likely to do. On the whole, therefore, it may be assumed that 2.5 per cent is a fair original cost for painting, and if the same amount is expended once in five years, one-half of one per cent. only is the annual cost of this item of maintenance.

One manufacturer of a special coating gives a table said to have been compiled from actual experience, in which the following costs are given for his special material:

Kind of Bridge.	Span.	Cost of paint per two-coat application per 100 lbs. of steel.
Highway	20	$0.08
Highway	40-60	.06
Highway	80-300	.03
Railway	80-300	.02

It is claimed for this special material that a new application need be applied only once in ten years. This makes the percentage cost of paint per annum on the basis of $85 per ton of steel as follows:

Kind of Bridge.	Span.	Per cent. per annum
Highway	20	1.88
Highway	40-60	1.41
Highway	80-300	0.70
Railway	80-300	0.47

Collecting together now the several points discussed, a recapitulation will be as follows:

Yearly costs of inspection should be about equal, for the two classes of structures.

Depreciation and consequent sinking fund requirement for steel at least 5 per cent., for concrete not to exceed 2 per cent.

Cost of maintenance of timber if used:

For steel highway structure about 4 per cent.
For steel railway structure about 1 per cent.

Cost of maintenance of regular pavement or earth road:

Surface for concrete structure less than 1 per cent.
Of regular ballasted railway track less than 1 per cent.

Cost of painting:

Steel railway structure less than 1 per cent.
Steel highway structure less than 2 per cent.

Total maintenance costs aside from interest on first cost for steel structure from 7 to 11 per cent., depending on character of bridge and kind of flooring.

For concrete structure not to exceed 3 per cent.

Excess of steel over concrete from 4 to 8 per cent.

This is a rough average percentage figure, therefore, which a company or community should allow in the first cost figure of a concrete bridge structure over the total cost of a steel structure for foundations and superstructure combined, in a true competition between the two classes of bridges. Of course the interest charge is to be added in each case. In other words, 3 per cent. of the cost of the concrete structure should be compared with 7 to 11 per cent. of the cost of a competing steel structure, and that type should be selected which will give the lower result.

Or, as a special example, if the lowest responsible bid for a concrete arch is $12,000, the yearly cost to the community will probably be 4 per cent. (assumed interest charge) plus 3 per cent. for depreciation and maintenance. Since the yearly costs for a steel structure will amount to from 11 to 15 per cent. total (4 per cent. assumed as above for interest) for the steel superstructure and slightly less for the abutments, then unless the steel bridge complete can be erected for from $6,000 to $8,000, its maintenance and interest charges will be greater than those of a concrete structure. That is, finally, it may, under certain circumstances, be more economical to pay from one and a half to two times as much in first cost for a concrete structure as for one of steel.

In indirect confirmation of this conclusion, may be cited the well known policy of the Pennsylvania Railroad, through the past decade especially, to replace all steel bridges with masonry ones as fast as their rebuilding became necessary.

No numerical value can be placed upon the artistic difference between the two materials. Steel arches have been erected which are exceedingly graceful and pleasing to the eye. The Washington

Arch over the Harlem River is a beautiful example of such a structure, and, on the other hand, it must be confessed that there are practically no concrete arches in this country which can compare in artistic design with this somewhat exceptional specimen of steel construction. In Europe are several examples of exceedingly pleasing concrete arches, especially in the mountainous districts, and it is hoped that this country may soon see a large number of structures erected which will rank in artistic appearance with those abroad and ably second the reputation in this country for concrete bridge design which now rests largely with the Connecticut Avenue Bridge in Washington and the Walnut Lane Arch in Philadelphia.

REINFORCED CONCRETE RETAINING WALLS.

By A. E. Lindau, Assoc. M. Am. Soc. C. E.*

Reinforced concrete has obtained prominence in the construction of retaining walls, in response to the universal demand for economy. So long as it serves the purpose as well as, or better than, other materials, and is as cheap, or cheaper, either in the matter of first cost or maintenance,—just so long will it maintain its position.

We must admit that frequently other factors may govern the choice of materials and type of construction. Indeed, some engineers advocate plain concrete even though reinforced would be cheaper, on the ground that stability can only be certain when the structure in itself has sufficient weight to resist overturning; and again, that mass is required to absorb shock and vibration. As to the latter, time and experience alone will furnish evidence, and for the present it must remain a matter of personal opinion. Regarding the former, it will probably be conceded that the stability of any retaining wall depends principally on the allowable soil pressure, and the coefficient of friction between the foundation and the wall and the foundation material. The allowable soil pressure governs the rotation of overturning of the wall, and the coefficient of friction, the sliding on its base. If in any case these quantities, in addition to the pressure of the retained material, are known or assumed, the comparative stability of mass concrete or reinforced retaining walls becomes entirely a matter of mechanics.

First Cost.

The advantage in first cost of reinforced concrete over plain is largely due to the fact that in the former, stability can be obtained by utilizing the weight of the retained material to prevent

* Chief Engineer, Corrugated Bar Company, St. Louis, Mo.

rotation and sliding, while the latter, the structure itself, must be heavy enough to remain in position.

To get a definite idea of the relative advantage, let us consider two simple cases of earth retaining walls—one a comparatively low one, say 10 ft. high, and the other 25 ft. from top of wall to bottom footing.

Ten Foot Wall.—For the low wall we will adopt the cantilever type for the reinforced design, similar to Fig. 1,* which

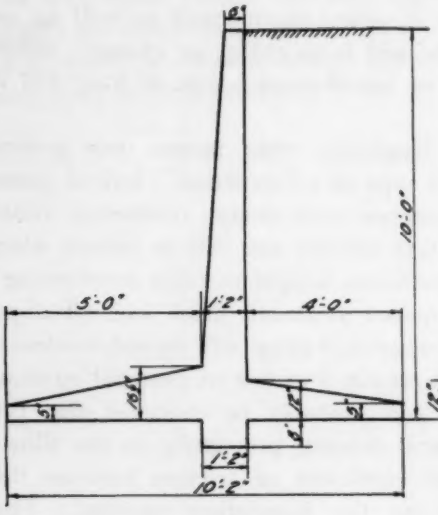


FIG. 1.

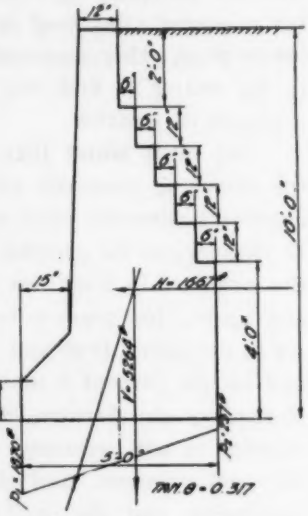


FIG. 2.

illustrates a wall built for the building of the Oak Leather Company in Cincinnati. It is to be noted that in Fig. 1 the width of base is equal to the height of the wall; which is only necessary where the soil has exceedingly low carrying capacity, and also that the vertical wall is placed in the middle of the foundation slab. The question naturally arises as to the most economical position of stem with reference to the base, and a little consideration of this feature may be of assistance in selecting the best design.

We will assume an earth fill with horizontal upper surface in which the horizontal pressure is one-third of the vertical and

*Acknowledgment is made to *Concrete Engineering* for the line cuts in this paper.

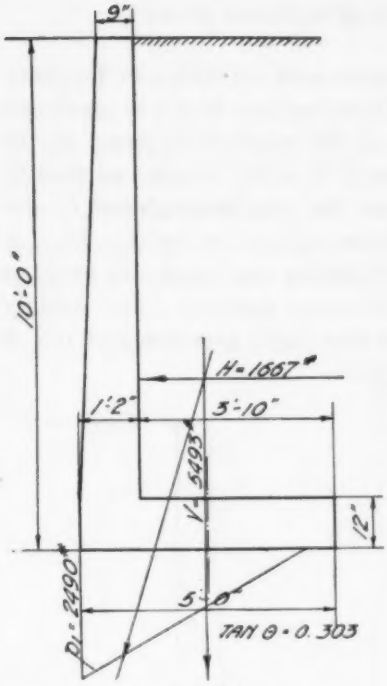


FIG. 3.

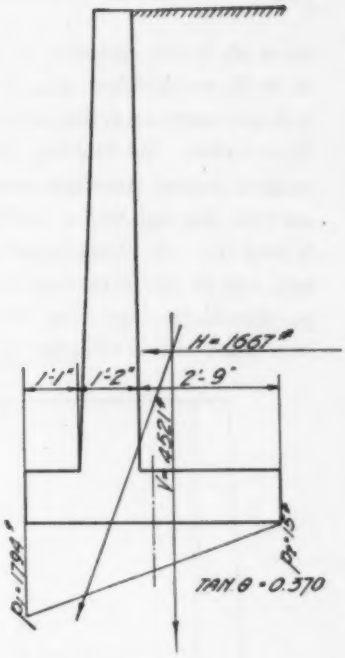


FIG. 4.

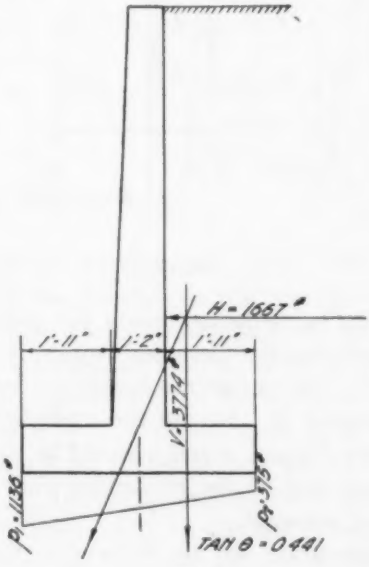


FIG. 5.

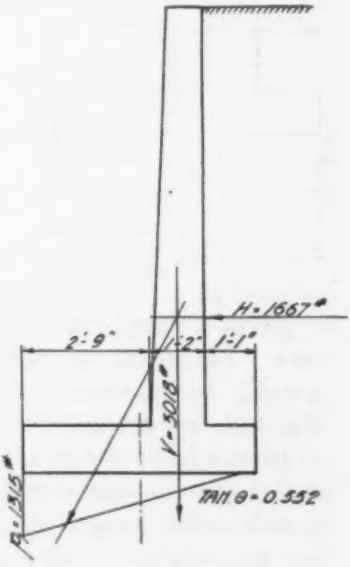


FIG. 6.

then shift the position of the stem with reference to the base, as is shown in Figs. 3, 4, 5 and 6, noting the change in maximum soil pressure and the direction of the resultant pressure on the foundation. By making the base 5/10 of the height, we shall be nearer actual average conditions, but the investigation is also carried through for a width of base 6/10 of the height (Figs. 7, 8 and 9). In these figures p_1 indicates maximum soil pressure and tan θ the direction of the resultant pressure. For stability p_1 should be less than the allowable earth pressure and tan θ less than the coefficient of friction.

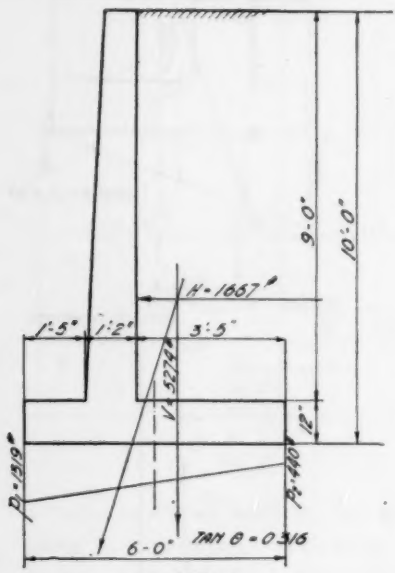


FIG. 7.

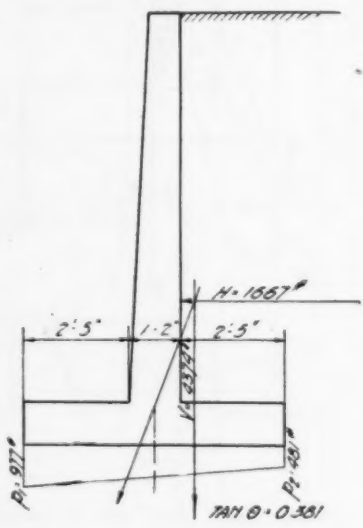


FIG. 8.

Fig. 3 shows maximum and Fig. 5 the minimum soil pressure. Tan θ on the other hand steadily increases from Figs. 3 to 6. In the series 7, 8 and 9, Fig. 9 has the lowest p_1, but Fig. 7 the minimum value of tangent θ. Should the coefficient of friction be limited to 4/10, then Figs. 5, 6 and 9 would be excluded from further consideration, and of the remainder Fig. 3 is unfavorable because of the soil pressure.

By the above process of elimination, we are reduced to the consideration of Figs. 4, 7 and 8, which may be compared with

a typical design in plain concrete, Fig. 2. We find here that the maximum soil pressure is greater than in the reinforced concrete design, making the plain concrete less desirable in point of stability instead of more so than the others.

Of the three figures referred to, 7 and 8 have more concrete than 4 and about the same amount of reinforcement; consequently, of all the reinforced designs considered, Fig. 4 is perhaps the most desirable. This design requires about 13.65 cubic feet of concrete per lineal foot of wall, while the plain concrete

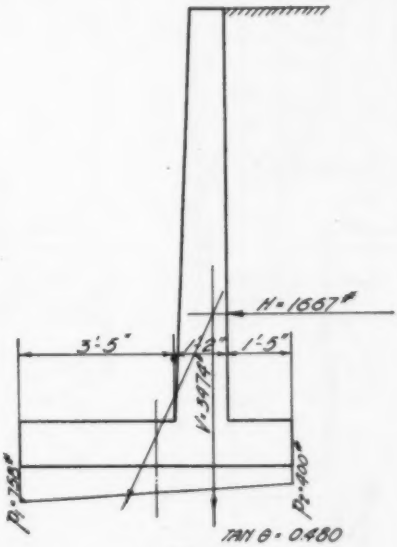


FIG. 9.

design requires 28.7 cubic feet; if to the cost of the former is added the cost of the reinforcement, the extra cost of handling concrete and additional fill, there will still remain a saving of about 25 per cent. in favor of the reinforced design.

Twenty-five Foot Wall.—Figs. 10, 11 and 12 show diagrams of a 25-ft. wall with base 6/10 of the height and the position of the stem varied as in Figs. 7, 8 and 9.

In this series, Fig. 12 is undesirable because of the tendency to slide. Fig. 11 has the advantage over Fig. 10 in point of soil pressure, and also the amount of reinforcement which would lead to the adoption of this design for the cantilever type. In Fig.

13 we have a plain concrete wall and in Fig. 14 a counterforted reinforced wall. Computing quantities we find that—

Fig. 10 requires about 100 cu. ft. of concrete and 260 lbs. of steel;

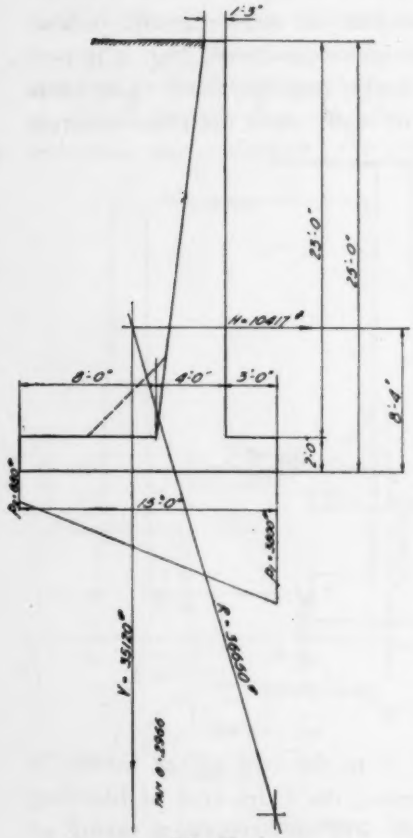


FIG. 10.

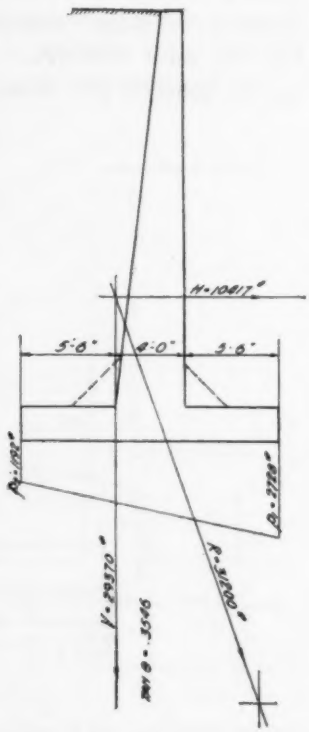


FIG. 11.

Fig. 11 requires about 97.25 cu. ft. of concrete and 218 lbs. of steel;

Fig. 13 requires about 151 cu. ft. of concrete;

Fig. 14 requires about 70 cu. ft. of concrete and 210 lbs. of steel;

All per lineal foot of wall.

It is evident that the counterfort wall is a cheaper type than the cantilever; we have, in fact, exceeded the height in which the cantilever type is desirable. Allowing again for the extra cost of placing concrete and form work, the reinforced wall will show great saving over the plain concrete—the relative amount of which will depend on local conditions.

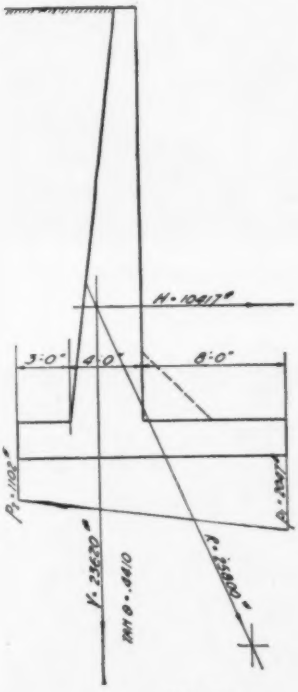


FIG. 12.

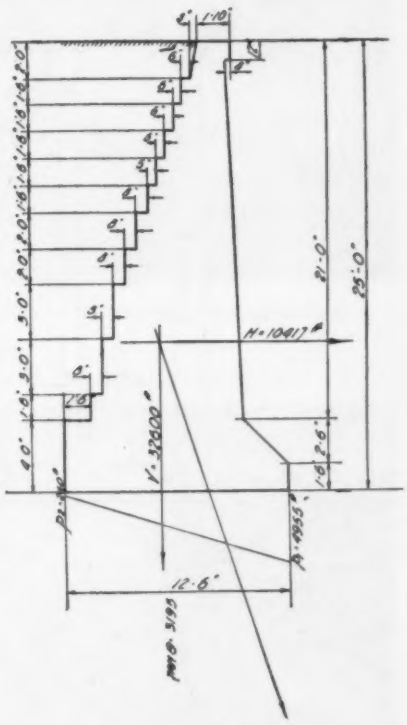


FIG. 13.

In the *Engineering News* of February 16, 1906, Mr. Frank Bone shows a saving of 63 per cent. in a 21-ft. wall by using reinforced concrete. Mr. C. F. Graff, in connection with retaining walls for the Great Northern Railway, estimated a saving varying from 20 to 45 per cent. In the *Engineering News* of January 5, 1905, Mr. F. F. Sinks makes a comparison between a plain and reinforced wall about 22 ft. high, showing a saving of $1.15 per lineal foot of wall.

In the point of first cost then there seems to be little question as to the advantage of reinforced concrete over plain when placed on the same basis with regard to stability.

MAINTENANCE.

Concrete has an unfortunate tendency to crack, principally due to changes in temperature, but whatever the cause may be,

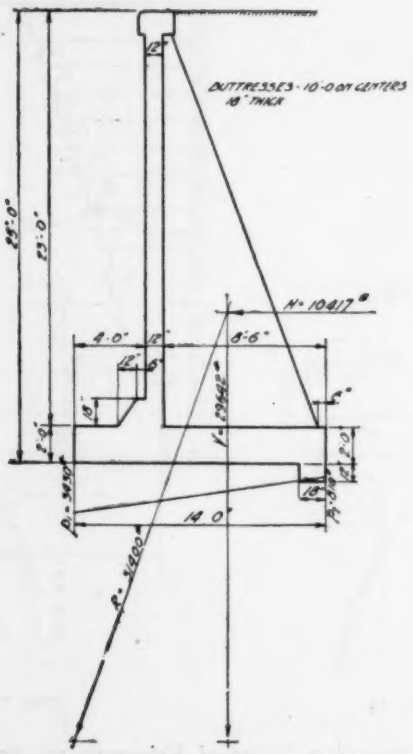


FIG. 14.

cracks frequently develop that affect the efficiency and life of the structure. In plain concrete retaining walls, this difficulty is met by building short sections and leaving definite joints between them, thus confining the expansion and contraction to these joints, but sometimes these joints fail to work, and in other

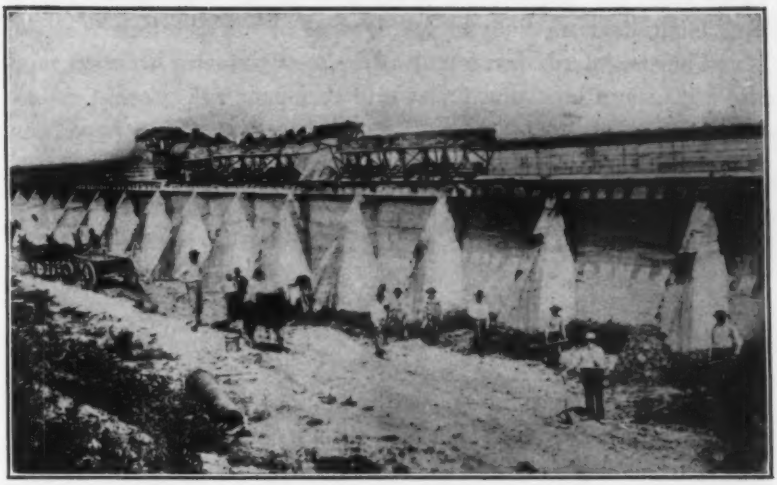


FIG. 15.—DIVIDING WALL IN RESERVOIR OF INDIANAPOLIS WATER COMPANY.

FIG. 16.—ABUTMENT AT SANGAMON RIVER BRIDGE.

cases they are impractical, wherefore it becomes important to find some other methods of taking care of the situation.

The use of reinforcement offers a satisfactory solution, and while it cannot be claimed that reinforcement will prevent cracks in structures of indefinite length, some excellent results have been obtained in walls several hundred feet long.

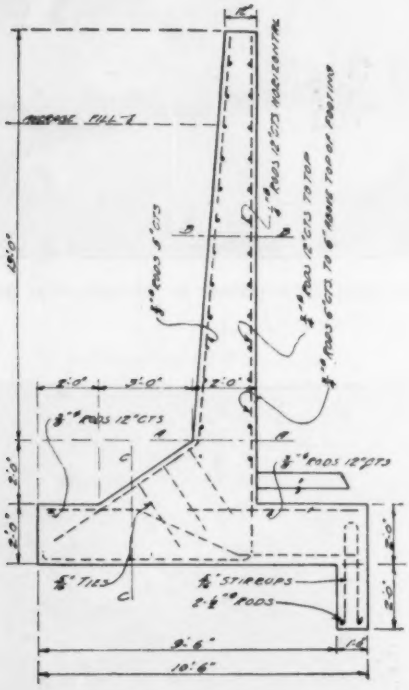


FIG. 17.

EXAMPLES OF CONSTRUCTION.

To those who have not had access to the literature on the subject, a few illustrations of typical work may be interesting as well as instructive. In no branch of engineering design is experience a more valuable aid than in retaining wall work, and at the same time examples more useless, unless the local conditions in each case are fully understood. Retaining walls are

built in which the thickness is 20 to 25 per cent. of the height; where the earth is hard and dry, and remains so, nothing further is heard from them. In other cases the thickness may be 50 or 60 per cent. of the height and still fail to keep the wall in position.

In Fig. 15 is shown a dividing wall in the Indianapolis Water Company's Reservoir. The wall is 350 ft. long and 12 ins. thick.

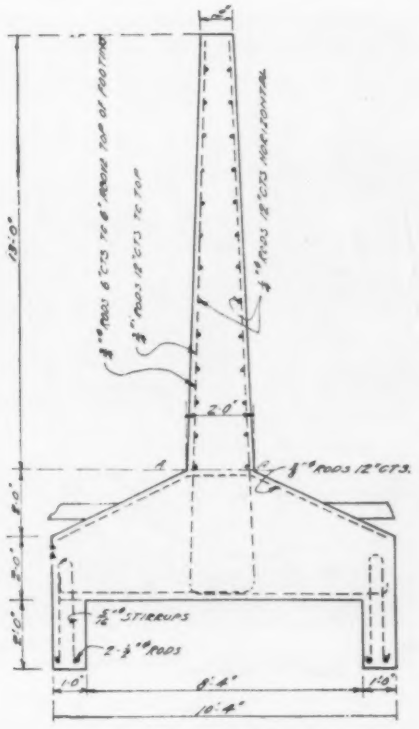


FIG. 18.

Without waterproofing this wall has in the course of operation of the reservoir withstood a full head of water on one side without showing appreciable leaks.

Fig. 16 shows reinforced concrete abutment of Sangamon River Bridge, Wabash Railway, and plain concrete retaining wall to protect embankment in high water. The abutment is hollow

or of cell construction. The side walls are 70 feet high and connected by cross walls; a reinforced slab carries the track and six feet of fill. The whole abutment being supported by piles called for the lightest possible structure consistent with strength. While much lighter than a plain concrete abutment, it is improbable that a passing train would cause appreciable shock or vibration, or in any way affect this abutment than one of plain concrete.

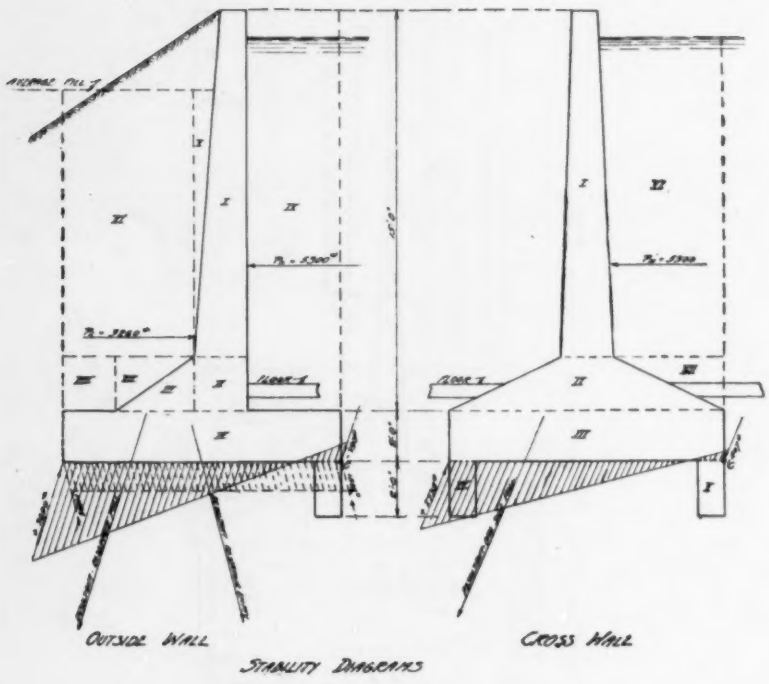


FIG. 19.

The bank protection wall also rests on piles; a portion of this wall has a thickness of 5/10 and the balance 4/10 of the height, yet on receiving the full pressure of the fill, a little leaning outward at the top was noticed,—not enough to make any difference in the efficiency of the wall, but sufficient to show that lateral earth pressures exist not only in theory, but in fact.

Figs. 17, 18 and 19 show methods of construction and finished structure for 3,000,000 gallon reinforced concrete reservoir,

Pine Bluff, Ark. The exterior walls are designed to take full head of water on the inside without assistance from embankment, and to take thrust from embankment on the outside when reservoir is empty,—the dividing wall to take full head of water on either side. Figs. 20 and 21 show views of this reservoir.

To prevent sliding on the base and also the formation of water pressure under the foundation, vertical walls or aprons

FIG. 20.—3,000,000-GALLON REINFORCED CONCRETE RESERVOIR.

are built at the edges of the foundations as shown in Figs. 18 and 19. The design of these walls was the result of careful consideration of the cost of various types, there being absolutely no prejudice in the matter, and the reinforced concrete cantilever was adopted because it was the cheapest wall for this particular situation. The concrete cost approximately $7.50 per yard in place in the walls, of which the forms averaged about 7 cents per sq. ft. of surface. The reinforcement averaged about 65 lbs. per cu. yd. of concrete and cost about $2^6/_{10}$ cents per lb. in place.

It was fully predicted when the Palouse retaining wall was built that it would not stand,—did not have weight enough, etc., but so far these predictions remain unverified. The wall has a maximum height of 32 ft., an over-all length of 795 ft. width of base 17 ft. The face wall is 7¾ ins. thick at the top and 14¾ ins. at the bottom, buttresses 12 in. thick and spaced 8 ft. apart, the foundation solid rock. The cost of the wall was $18.00 per cu. yd.—an unusually high figure, due to unfavorable conditions. According to the contractor, it could be duplicated at present prices of material and labor for one-half of the original

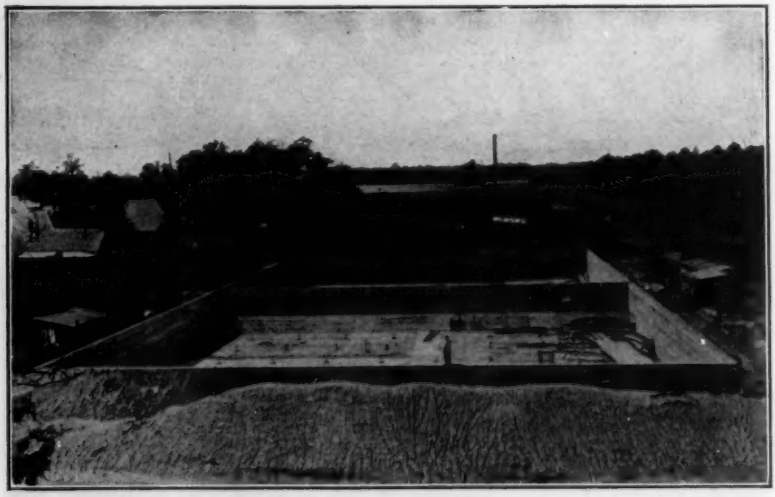


FIG. 21.—3,000,000-GALLON REINFORCED CONCRETE RESERVOIR AT PINE BLUFF, ARKANSAS.

cost. It may also be of interest to note that we have here a stretch of wall nearly 800 ft. long without expansion joints, and has so far not shown any cracks.

Although, strictly speaking, not a retaining wall, the abutment at Cahaba River Crossing, A. B. & A. R. R., shown in Fig. 22 is of interest because it is probably the highest buttressed abutment that has so far been built. The height from base to top of parapet is 61 ft. The width of base is 35 ft. 6 in. at the middle section. The maximum soil pressure about 12,000 lbs. per sq. ft., but as the foundation is rock, this is a very safe figure.

A very extensive and typical reinforced concrete retaining wall construction is used for the settling basins at the Chain of Rocks, St. Louis, Mo. Sections of this wall, five or six hundred feet long, stood without the protection of embankment, through changes of temperature from summer to winter without cracking. Other cases of similar nature could be cited to show that it is possible, by means of reinforcement, to prevent serious cracking in concrete retaining walls. Although difficult to reduce to figures, this property of reinforced concrete repre-

FIG. 22.—ABUTMENT AT CAHABA RIVER CROSSING.

sents a distinct economy in maintenance and should be given consideration in weighing the advantages and disadvantages of plain and reinforced concrete.

These basins are each 827 ft. by 400 ft., founded on comparatively soft and uncertain material, which is common on the banks of rivers. The walls are 24 ft. high and the footing 25 ft. wide; the face wall is 18 in. thick under the coping, increasing to 30 ins. at the bottom; buttresses are 18 ins. thick and spaced 16 ft. apart. The concrete for the walls is a 1:3:6 mix, and

21,900 were cu. yds. required, costing $7.60 per yard in place, not including the reinforcement. The reinforcement totaled 930 tons or about 85 lbs. yer cu. yd.

CONCLUSION.

From our brief and limited examination of the subject, we are scarcely justified in drawing general conclusions, but the following may serve until time and experience has placed the matter on a more definite basis:

For the same strength and stability a reinforced concrete retaining wall will in general cost less than one of plain concrete.

In reservoirs, or other construction where joints are undesirable, the use of reinforcement is of particular advantage.

The stability of reinforcement to prevent, or distribute, cracks, so as to make them inappreciable, is valuable in adding to the appearance and life of the structure.

The truly monolithic character of reinforced concrete retaining walls gives them reserve strength to meet unlooked for conditions.

The writer is indebted to the Water Department, City of St. Louis; to A. O. Cunningham, Chief Engineer, Wabash Railroad; Wm. P. Carmichael Co., Contractors; the Engineering Department A. B. & A. R. R., and the current technical literature for much of the detail information in connection with the above.

DISCUSSION.

MR. W. P. ANDERSON.—There is one point as to the relative cost of the cantilever and buttress wall not brought out in the paper, and I think too often overlooked by the designing engineers, and that is, in using a buttress wall you may materially cut down the quantity of concrete per superficial foot of form work. In the case mentioned the concrete was reduced 30 per cent. per running foot of wall. In the paper just read there was as much form work for the main part of the wall as for the cantilever, and in addition to that there was form work for the buttresses. In a concrete building the cost of the form work is greater than the cost of all the labor and all the material in the concrete, so that it is a very material item. In a retaining wall the case is different, because the base of the wall, which is probably one-third of the bulk, will need very little form work. However, in using a buttress wall the thickness of the wall is reduced on account of the buttresses. The buttresses, being closer together than the height of the wall, make it possible to use $\frac{W\,L}{10}$ in figuring the moments, instead of the moments required for the cantilever. But in the case of a buttress wall, say 8 ins. thick, the form work will cost anywhere from $4 to $5 a yard; that is, for a thin buttress wall of that kind. I want to call your attention to that fact, that while a buttress wall compared with a cantilever wall may have some advantages with reference to cost, I do not believe that its advantages are so great as would seem by not considering the cost of the form work. Mr. Anderson.

MR. A. E. LINDAU.—This was given consideration before the paper was written, but omitted because the cost of form work varies so in each individual case. It was intended to bring out the great saving in the buttressed wall over the cantilever. In the particular case under discussion it would, of course, have Mr. Lindau.

Mr. Lindau. been much more interesting if time and opportunity had been given to consider the point at which the buttressed wall becomes economical and the point at which the cantilever wall ceases to be so. I believe it is about 25 feet or at least below 25 feet, even considering the extra cost of the form work and of placing the concrete wall in thinner sections.

As to the cost of form work in proportion to the cost of concrete per cubic yard, I think that in any section of the country, where it costs as much as $4 per cubic yard for form work on an 18 to 30 in. wall, that the contractor who figured $7 per cubic yard for the work would not be able to come out alive.

Mr. Anderson. MR. ANDERSON.—I gave that figure for an 8 in. wall

Mr. Lindau. MR. LINDAU.—Well, of course it would be a very much greater cost per cubic yard in that case.

Mr. Davis. MR. B. H. DAVIS.—I would like to ask the following questions:

1. What is the most economical spacing of buttresses in the type of retaining wall in which they are used?

On two of the walls of the buttressed type discussed by Mr. Lindau, the buttresses were spaced 8 and 16 ft. respectively, center to center. I should like to inquire if these figures do not represent two extremes, perhaps, between which there may be some economic mean. After a considerable discussion, the buttresses were spaced 12 ft. 6 ins. center to center, in the case of the retaining walls in connection with the Buffalo Track Elevation of the D., L. and W. R. R.*

2. Where does the economy in the use of the buttressed type of wall cease and that of the cantilever type begin, or below what height of wall does it become more economical to build the cantilever in preference to the buttressed type of retaining wall, which is ordinarily used only for walls of considerable height?

This point was discussed in the paper, but I did not understand clearly at just what height of wall the substitution of one type of wall for the other was deemed economical and advisable.

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*See p. 281 for view of one of these walls.

3. Is it practicable to place a wide and massive appearing coping on a thin reinforced concrete retaining wall, without danger of frost lifting or heaving it from its support? Mr. Davis.

One of the most common objections raised by railroad companies against the reinforced concrete retaining wall, is its light and so-called flimsy appearance. Being accustomed to massive stone copings of standard 3 ft. width, very naturally anything lighter than this in reinforced concrete, has to meet with every conceivable kind of objection, from aesthetic considerations down to what the frost might do to the wall, if nothing else can be found to condemn it.

4. What has been found to be the most effective method of keying or bonding adjoining sections of reinforced concrete retaining walls?

The "groove and tenon" joint shown in the section of C., B. & Q. R. R. retaining wall has not proven altogether satisfactory where it has been used in plain concrete walls of gravity section. One section of wall settling more than the one adjoining invariably cracks one or the other or both sections.

Some better method of bonding adjoining sections of plain or reinforced concrete retaining wall are probably known to some of the members present, and it is hoped that they will give this convention the benefit of their experience on this and other subjects under discussion.

MR. LINDAU.—The first question is important, and it would be a very valuable thing to extend the investigation along that line. I think that perhaps the Water Department of St. Louis, Mo., in selecting their type of wall, examined the influence of the spacing of the buttresses for economy. But I think the 8-foot spacing decided upon in the Palouse retaining wall is too short; the spacing used in the wall at St. Louis is probably very much better. It is a problem which can easily be solved by making a number of designs and estimating the cost of the various items entering into them. In reference to the base and the economy of location, it is very likely that you will find that the cost will vary with heights of walls. Mr. Lindau.

Mr. Lindau

In regard to the coping, the construction of the St. Louis reservoirs would answer the question. The coping is 2½ to 3 ft. wide, and by letting the vertical bars of buttresses run up into the coping and by reinforcing that coping horizontally, the action of frost can be taken care of.

The bonding of sections of a wall is a point that I cannot answer fully. I can quote in a general way from a letter furnished me by the Burlington Railroad in regard to their walls, which are joined at frequent intervals by vertical dove-tail joints. I asked them about the stability and character of their walls, and they state "As to stability and cracking, you may know that foundations here are very uncertain. We have had very little trouble with cracking due to foundations. We have had a little tipping in a few instances. Some of this has been forward and some backward." It seems, therefore, that the stability of concrete walls is merely a matter of soil pressure. With good foundations the walls will neither tip or crack. The difficulty with all reinforced concrete retaining wall work—in fact, any retaining wall work—is knowing the conditions.

Mr. Anderson.

MR. ANDERSON.—Very often in designing a cantilever wall it is necessary to make a right angle turn. The top of the wall deflects or moves out when the earth fill has been placed behind the wall, and this will, in some cases, put a strain on the corner. This should be taken care of, as the strain is pretty great. We built a wall about 30 ft. high, and I suppose the movement on the top due to the back fill was 1 inch or more, and this caused a big crack in the side of the wall. If I were going to design a wall of that kind myself again, I would leave a joint there, as this is easier than putting in steel, although when you build a joint you have the possibility of frost getting in and causing trouble. The crack can be filled up after the wall is erected and the dirt put behind it, because then no further movement of the top of the wall is likely to occur.

Mr. Lindau.

MR. LINDAU.—I would again refer to the wall of the St. Louis Settling Basins, where such construction was necessary. Of course they had special conditions and because of waterproofing they did not make any joints. One of the walls stood, I think, over the winter without any earth backing, and then the

earth backing was put in, and I had occasion to examine that wall very carefully for cracks, particularly at the corners. I expected to find some, but could discover no evidence of cracks anywhere. Mr. Lindau.

MR. EMILE G. PERROT.—I would like to corroborate a statement made in regard to lack of value of the outside filling against a retaining wall. We had a sad experience with a retaining wall about 20 ft. high and 100 ft. long, in which we tried to get some value out of the outside fill. After the building was up for some time the whole wall shifted several inches, so that we had to put buttresses on the outside wall to keep it in position. This shows that in designing retaining walls it is absolutely necessary to consider the wall the full height. If there is a fill on the outside, as soon as it rains that fill settles, and usually settles away from the wall. Mr. Perrot.

THE APPLICABILITY AND COMPARATIVE COST OF CONCRETE AND REINFORCED CONCRETE FOR SUBWAY CONSTRUCTION.

By Charles M. Mills, M. Am. Soc. C. E.*

Concrete has been used in building metropolitan underground railways from the beginning of such construction. It was used in the structure of the Metropolitan District Railway in London, authorized by Act of Parliament in 1854, construction beginning in 1860, the successive extensions not being completed until 1884. It was used in backing the haunches of the brick arches, in the footings of masonry sidewalls, in backing behind the sidewalls as the timbering was removed, and later in the sidewalls themselves and in the inverts.

The advantages of concrete have evidently influenced the designs of all the underground railways to the present time. In the earlier construction stone masonry and brickwork predominated, but these have yielded to concrete as its properties and adaptability to meet varied requirements became better understood, its use receiving an impetus by the production of Portland Cement. With the addition of reinforcement, concrete has increased its claim upon designers and constructors, so that to-day it is indispensable, the combination possessing properties and affording facilities possible with no other material. In passing, it may be noted that in the railway subways in European cities, concrete has been used mostly without reinforcement, contrary to what might have been expected, while in America, in many cases, reinforcement has been liberally utilized.

The advisability and advantages of concrete both plain and reinforced for subways is so complete in most respects and is so well understood, that only the salient features will be noticed, with general references to economics.

* Principal Assistant Engineer, Subway and Elevated Railroad Construction, Philadelphia Rapid Transit Company.

To attempt to satisfactorily show by figures the savings effected by the use of concrete, either plain or reinforced, in subway construction, involves the consideration of many conditions to avoid producing misleading impressions. The extent of the permissible interference with street traffic, the nature and density of the traffic, the local costs of materials and the facilities for their storage and handling, the conveniences for handling the excavated material, as well as many other details, all affect the cost. In view of these considerations no definite figures will be given. It has been a surprise to the writer, that the aggregates of items of cost in different designs for subway structures, carefully developed with a view to economy, have varied so little, the differences being small percentages of the entire cost involved.

It is well understood that concrete may be made with ordinary labor under efficient direction, so that its unit cost, compared with that of brick work, is usually much cheaper, especially under the conditions which prevail in underground construction in busy city streets; and concrete, as compared with brick work for this kind of construction, is so superior that the use of brick work is now limited to collateral details, such as sewer work, underpinning and miscellaneous work at passenger stations.

For sidewalls sustaining earth pressure as well as vertical loads, reinforced concrete is especially advantageous, since the thickness may be made but a fraction of that required for walls of brick or stone masonry. Thin sidewalls reduce the width of the trench to be excavated, an important and costly item of work in city streets, and are usually necessary, since the available space under the beds of streets is frequently limited, either by existing structures, or by the necessary reservations for sewers or other underground structures, as municipal requirements increase.

Thin walls also may be built with vertical I-beams to resist the earth pressure with vertical jack arches of concrete between them. The cost of such walls is slightly more than for those of reinforced concrete, the comparison of cost including many details. The I-beams are usually 12 or 15 ins. deep and spaced 5 to 6½

ft. apart on centers, and require some thickness of concrete back of them to cover the outer flanges. In addition, protection of the beams from corrosion and the fact that the wall is pierced every 5 or 6 feet by the beams renders waterproofing necessary. The placing of waterproofing from the interior of the trench, requires a thin wall of brick or concrete outside of the beams. The total thickness of such composite walls, without concrete covering over the inner flanges of the beams is usually from 21 to 24 ins. The inner flanges of the beams being uncovered require painting which entails a maintenance charge. If the inner flanges of the beams are covered with concrete, the total thickness of the wall is increased, and this, together with the details requisite to efficiently secure the concrete to the flanges, are additional items of expense.

Little advantage, if any, in supporting traffic during construction is afforded by the beams, unless steel roof beams are used, since the timbering required prior to the erection of the beams may readily be designed to fulfil this purpose.

The sidewalls of reinforced concrete considered in the comparison of cost are taken 24 ins. thick, though 16 ins. would usually suffice to sustain all the stresses, the additional 8 ins. or 50 per cent. being placed for practical considerations, partly construction details and partly to diminish liability of leakage. As the thickness of the wall is increased for the reasons stated, the quantity of main reinforcement is diminished with the resulting saving. No waterproofing is considered in the reinforced concrete sidewalls, since with longitudinal reinforcement properly distributed in the walls, and with the cement and concrete aggregates properly proportioned, made to a wet consistency and well placed in the forms, the use of waterproofing is unnecessary under all heads of ground water liable to exist in ordinary subway construction, thus eliminating many troublesome details and simplifying the work.

An advantage of reinforced concrete sidewalls with longitudinal reinforcement is that no expansion joints are required, and long stretches of wall may be built without cracks due to changes of temperature or to shrinkage, or to be more exact with such a multiplicity of distributed minute cracks that they

are harmless, and invisible except under the closest scrutiny. The longitudinal reinforcement may be varied to meet the various

FIG. 1.—LONGITUDINAL RODS AND RABBETS TO MAKE JOINTS. PHILADELPHIA SUBWAY.

conditions, and to produce lesser or greater capacity to resist leakage as desired. (See Fig. 1.)

The simplicity and superior water tightness of well designed reinforced concrete sidewalls make them worth more than walls of beams and concrete jack arches even though local conditions might show a slight saving in first cost for the latter. It is probable that in most cases the first cost of reinforced concrete sidewalls will be a little less than that for the other type, but the difference will be a small percentage of the whole cost.

In the use of reinforced concrete for subways, both for sidewalls and roofs, plates of uniform thickness have generally been employed, instead of an alteration of beams and slabs. The refinement of workmanship required in placing concentrated reinforcement in beams, with shear rods, and the other details of beam and slab construction is injudicious from practical considerations in underground work. Such work is usually done in restricted space and with artificial light, so that good workmanship is secured only by the closest supervision and painstaking inspection. Though there be no desire to slight the work, the workmen are out of sight and simplicity of details is essential. Under the conditions, the cost of plates of uniform thickness, considering the cost of forms and their handling and of the reinforcement and its placing, is less than that for an alternation of beams and slabs, and compensates for the additional material required.

It is probable that with the advance being made in the production of assembled reinforcement handled in units, construction of roofs with an alternation of beams and slabs may be found advantageous, since economies may result to compensate for the additional expense now entailed by such designs, and methods devised to secure good work under the difficult conditions.

Since it is desirable to make the depth from the street surface to the passenger platforms as little as practicable, and the distance from the top of the roof to the street surface is usually determined by the space necessary for the water and gas mains, electrical conduits and other underground structures, the arched roof is often objectionable owing to the increased depth of the structure due to the rise of the arch. Flat roofs have been mostly employed with a moderate slope for drainage. Flat roofs are built of cross beams or girders with jack arches of concrete, and

also of reinforced concrete alone. Due to the considerations previously described the reinforced concrete roofs have been of plates of uniform thickness. Fig. 2 shows a flat roof construction.

Since the drainage grades on flat roofs are slight, and accidental leaks in roofs are more objectionable than when they occur in sidewalls, waterproofing is always used. In comparisons of the costs of roofs the item of waterproofing is common to all

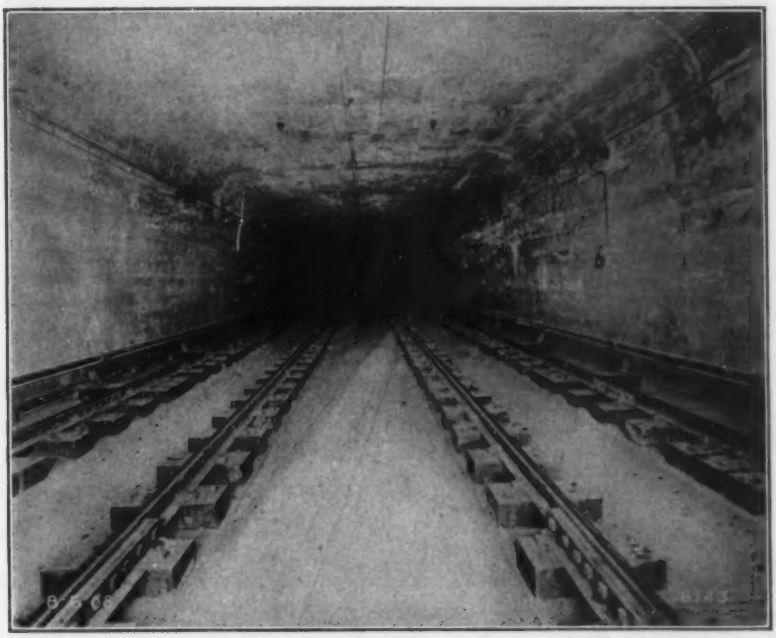

FIG. 2.—ROOF OF REINFORCED CONCRETE IN ONE SPAN OF 26 FT. 6 INS.; SIDEWALLS OF REINFORCED CONCRETE. PHILADELPHIA SUBWAY.

styles of flat roofs and reduces the elements of difference to the other features of the designs. The execution of permanent and watertight roofs with beams and concrete jack arches involves many details requiring care, and it may be said that greater simplicity and superior permanent results are obtainable with reinforced concrete alone.

With beams and jack arches, it is necessary to introduce reinforcement to prevent cracking due to shrinkage and tempera-

ture stresses, particularly immediately over the beams where the concrete is liable to crack and cause leaks, water tending to flow along the webs and flanges. Reinforced concrete in such places is superior to any other available material in securing enduring and watertight work. Another source of leakage where beams are used is the thinness of the concrete back of the ends of the beams where they rest on the sidewalls. Such roofs require

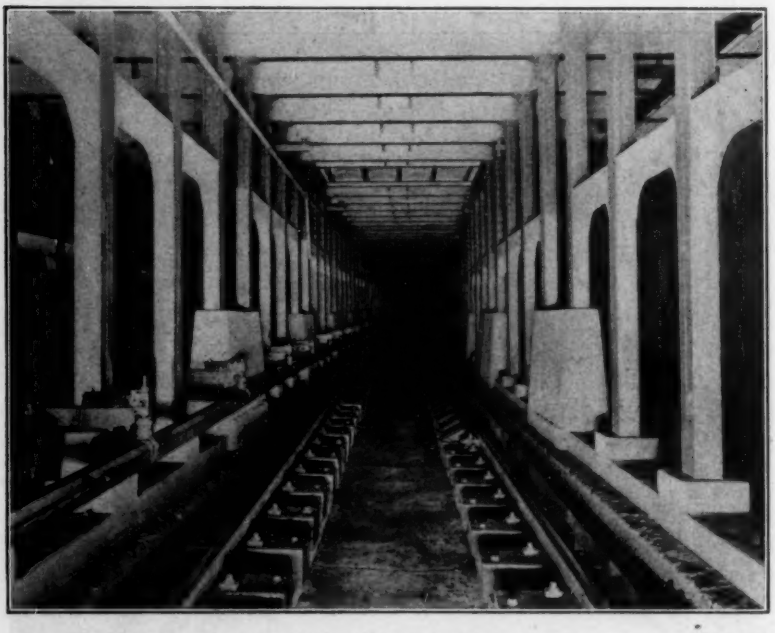

FIG. 3.—ROOF OF 20-IN. I-BEAMS WITH CONCRETE JACK ARCHES; SIDEWALL REINFORCED CONCRETE. PHILADELPHIA SUBWAY.

careful and efficient waterproofing, and but little dependence should be placed on the waterproofing to bridge over or seal cracks in the concrete. Fig. 3 shows beam roof construction.

The cost of flat roofs with transverse beams and jack arches of concrete is found to be cheaper than reinforced concrete roofs with plates of uniform thickness. This is partly due to a lack of economy of material in using plates of uniform thickness, and partly to construction details.

From the foregoing it appears that the first cost of a two-track subway with reinforced concrete sidewalls and a roof with beams and concrete jack arches may usually be found less than that of a structure entirely of reinforced concrete, but such inference should be considered with caution for the reasons previously indicated. The difference in cost if in favor of the beams and concrete jack arches would be but a small percentage

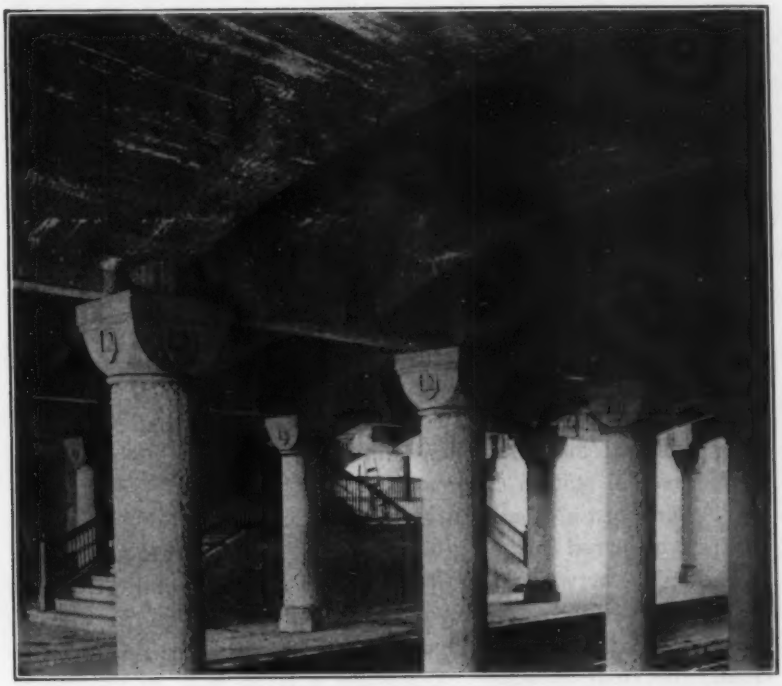

FIG. 4.—STATION, SIXTY-NINTH STREET TERMINAL. ALL OF CONCRETE EXCEPT BALUSTRADE.

of the entire expense. On the other hand the permanent advantages of an entire reinforced concrete structure are markedly great, and maintenance charges inseparable from composite structures of structural steel and concrete are eliminated.

As to the cost of various types of structures, it is possible that with space for masonry sidewalls in a subway for two tracks, and with the roof in one span and with favorable conditions,

economies might result, so that the cost of such a structure as a whole would not exceed that of one with thin walls of reinforced concrete and might be less.

Reinforced concrete permits the use of arched cross sections in cases where plain concrete or brick masonry would involve uncertain stability under the action of concentrated loads, particularly with the probability of the excavation of trenches parallel to and alongside of the structure. Consideration of the latter contingency is imperative due to the growing demand in cities for underground service for public utilities, and the growth of municipal improvements, by which increasing space is required beneath the streets.

In addition to the sidewalls and roofs of subways, the concrete plain or reinforced, is well suited for the construction of floors, inverts, platforms, stairways and other parts of underground railways. By using the precautions to exclude water by proportioning the constituents and reinforcement, concrete may be used for inverts or floors to better advantage than any other known material. This statement applies also to sumps, pumping chambers, underground passages and other deep construction, good results being obtainable with less expense than with any other material and much less difficulty. Fig. 4 illustrates use of concrete in station construction.

An interesting demonstration of the advantage of reinforced concrete occurred in the building of the Market street subway in Philadelphia, between the City Hall and the Schuylkill River, at Twenty-first street. A large water main on the north side of the street parted at the junction with a main on Twenty-first street, the rush of water excavating a large hole in the street and carrying the debris into the uncompleted subway. A small egg-shaped reinforced concrete sewer built as part of the drainage diversion caused by the subway construction, sustained itself as a bridge with a clear span a little over 40 feet wide, and not only carried its own weight, but also a quantity of earth, paving stones and other debris. No fractures were found in the sewer, only some small cracks, and the leakage from the sewer which had been in service for some time, amounted only to intermittent drops. The washout was backfilled and the street repaved with-

out the necessity for any repairs to the sewer. The incident confirmed the judgment exercised in the beginning of the work, to build the new sewers parallel to the subway of reinforced concrete.

In conclusion the author feels it necessary to recognize the fact that the matter presented does not completely comport with the title of the paper, since definite comparisons by figures, of the cost of concrete and reinforced concrete for subway construction are not furnished. Reviewing the data as to the cost of subways in several cities, representing various practice, it was not found practicable in the time available for the preparation of the paper, to prepare such comparisons, since so many diverse conditions, unless carefully considered, would make them of no practical value. Comparisons of the cost of modern and obsolete types have not been made, as they would be of interest only to the curious.

DISCUSSION.

Mr. Anderson. MR. W. P. ANDERSON.—I understand that no expansion nor contraction joints were left in the side walls of the subway, and I should like to ask if there is any rule for determining the quantity of longitudinal reinforcement in reference to the cross section of the walls; if there is no rule, about how much steel was put in?

Mr. Mills. MR. C. M. MILLS.—The action of longitudinal reinforcement as usually applied in walls or other structures of concrete to prevent cracking is more correctly described as distributing cracks than preventing them. With this reinforcement the total of the openings of a few large cracks at irregular or accidental intervals may be distributed among many small ones, and the reinforcement may be proportioned to make the subdivisions too small to be visible.

The quantity of longitudinal reinforcement might be made sufficient to so uniformly distribute the stretch in a concrete member with restrained ends, that cracks would not occur, provided the rate of stretch did not exceed that permissible in concrete acting in connection with reinforcing steel, which investigators have reported to exceed that in concrete without such steel. The use of such a quantity is unnecessary since a lesser amount suffices, and may be varied to meet the particular requirements of any case.

The amount of reinforcement or the total sectional area of steel required to produce a given effect is directly proportional to the diameter of the component sections and inversely proportional to their bonding value to the concrete, being the same whether round or square rods are used. Hence small sized rods, shaped or formed to augment the bond, are most economical in quantity. Due regard is necessary for extra cost of small sizes and the labor cost of handling many small pieces.

Mr. Mills.

Though the strands of wire fabric have less bonding value than plain rolled rods, and still less than shaped rods, their small diameter compensates for the low bonding value, which is augmented if the intersections are non-slipping. If wire fabric is used, the strands should be straight, and the strands should be placed straight in the work.

It is usually immaterial whether the usual grade of structural steel with about 30,000 lbs. elastic limit be used, or high elastic limit steel, provided the quantity is 0.3 per cent. or more. If the quantity is less than this, high elastic limit steel is desirable to avoid impairing the efficiency of the bond, especially if plain bars are used; fracture is out of the question.

The component sections should be uniformly distributed in the concrete, unless the faces of the work are unequally exposed to temperature changes, when the steel should be distributed to assist the mass most liable to crack.

The amount of longitudinal reinforcement in the side walls of the part of the Market street subway built last, is about 0.3 per cent. of ⅝ in. square cold twisted bars of 60,000 lbs. ultimate strength, no waterproofing being used. The subway is underdrained, and under other conditions the quantity of reinforcement might have to be increased. The cracks are very small, are well distributed, and are entirely unobjectionable, the structure being practically dry. Though the structure is underdrained, in many cases the backfilling contained clay by which water is retained above the drains, especially in protracted wet weather, so that the efficiency of the walls to resist leakage has been thoroughly tested in many places. Where leakage has occurred the joints between successive sections of the concrete work were not properly made, and the number of leaks is very small.

The production of watertight walls depends both on making dense concrete and the proper use of the reinforcement in proper quantity. The concrete in the sidewalls was made with graded aggregates and mixed wet, requiring but a moderate amount of spading and tamping.

The quantity of reinforcement used in the subway walls is serving under moderate changes of temperature, approximating 50 degrees; in cases subject to greater extremes more would be

Mr. Mills. required, probably 0.4 per cent., and where watertightness is desired without dependence on the infiltration of clay or other fine material to seal fine fissures, the quantity might have to be made 0.5 per cent.

Atmospheric temperature conditions are not the only considerations, since the shrinkage in the hardening of concrete in air and the contraction caused by the cooling following the chemical reactions in setting and hardening tend to produce cracks.

THE ADVANTAGES OF REINFORCED CONCRETE FOR RAILWAY CONSTRUCTION.

By B. H. Davis.*

The advantages of reinforced concrete as a building material for railway construction are indeed many as compared with its few disadvantages which may more properly be termed its limitations. Where it is possible to use reinforced concrete for a part or all of a railway structure, it is generally of advantage at least in the long run to make use of this practically indestructable material.

In reinforced concrete there is a combination of the good qualities of two most valuable building materials—steel and concrete—and each of these constituents supplies to their combination the deficiencies which each in itself possesses to its detriment when used singly. The fireproof, corrosion proof, and decay proof qualities of reinforced concrete commend it most highly for all classes of structures where permanent construction is desired. For railway structures, perhaps more than any other class of structures, are these qualities particularly desirable. The reason for this is self-evident, for though a mine may soon be worked out, or a mill or an industrial concern dependent upon the local supply of raw material may have but a limited period of usefulness, yet a railway, on account of its varied sources of revenue in each locality, and by its very nature independent of purely local conditions, once substantially built, is expected to be perpetual in its usefulness.

Constantly increasing maintenance costs are no doubt directly responsible for the growing demand for permanent construction wherever possible, especially among conservatively and wisely managed railroads. Therefore from the railway standpoint the introduction of reinforced concrete as a building material enjoying as it does a wider range of possible uses and

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varieties of design than any other known building material, and yet so admirably adapted to meet all the requirements of the case in regard to permanence, was indeed most opportune.

In the following discussion the aim shall be, first, to present for consideration a few of the familiar uses of reinforced concrete as applied to railway construction; second, to point out as clearly as possible the advantages and disadvantages resulting from the use of reinforced concrete in each case, and third, to compare their costs, where such data is available, with the costs of similar structures built of other materials. A few photographs are shown to illustrate types of construction as they are discussed.

The suddenness and completeness with which plain concrete supplanted stone and brick for all ordinary railroad masonry structures and sub-structures, is ample proof of its many advantages over the other materials. It will not be necessary therefore to analyze the causes of this sudden change, except to note that plain concrete was the forerunner of reinforced concrete, and thus deserves mention in a paper on the latter subject.

PLAIN CONCRETE.

The use of plain concrete in bridge piers, abutments, and wing walls, retaining walls, foundation walls, station platforms, arch culverts and arch bridges led up to old rail reinforcement of flat top culverts familiarly known as rail top culverts, which was perhaps the first attempt at reinforcement of concrete in a railway structure.

RAIL TOP CULVERTS.

The deservedly great popularity of the old rail top culverts, was largely responsible for the ready acceptance of reinforced concrete when its advocates finally offered it to the public.

In the way of permanence the old rail top culvert had all the advantages of the more modern bar-reinforced box culvert, but it was not an economical reinforced concrete structure on account of the great excess of steel required. Indeed, it is doubtful if it could properly be termed anything but a protected steel structure, for most engineers in designing them, count

upon the steel to carry the load, totally disregarding the concrete except as a protection to the steel. When it is found impossible to pack a sufficient number of old rails in a given section, to give it the desired section modulus, I beams are sometimes substituted for the rails, or for every second or third rail, much to the improvement of the structure as regards reliability.

EMBEDDED I BEAM CULVERTS.

A great deal of excellent work has been done with the embedded I beam construction, but it is certainly erroneous to call this combination of steel and concrete reinforced concrete. It is better than the old rail construction because the section of each I beam is known, while the old rails are more or less worn, and liable to have dangerous invisible flaws. Moreover it would require a mathematician of no mean ability to compute the section modulus of some of the old rails frequently used, if the design were to be accurately made in one case as in the other. A further use of the embedded I beam construction is made in carrying one track over another as is frequently done in the grade separation of two railways intersecting at a difficult angle since the I beams are more easily and positively connected to the longitudinal steel girders than the old rails.

Very long and expensive skew spans are often avoided by the use of the long structure of short, light spans, as is so well illustrated by the Pennsylvania Crossing of the Delaware, Lackawanna and Western, west of Bergin Hill, N. J.

REINFORCED CONCRETE BOX CULVERTS.

If the spans are not too long and the head room also limited, reinforced concrete slabs could be used economically in such cases. This question of head room often necessitating a very shallow floor system, brings into prominence one of the limitations to the use of reinforced concrete, namely, the case of long spans of very limited depth where its use is practically impossible or at least not economical. Where the conditions are not too severe, economies of masonry and steel are possible through the use of reinforcement in side walls, top slab, and inverted slab of reinforced concrete box culverts and subways.

SMALL CULVERTS.

An interesting though perhaps not very important use of reinforced concrete as applied to railway structures is found in small culverts. On part of a rather heavy railroad construction recently undertaken, it was decided that no smaller openings than that furnished by a 24-in. cast iron pipe would be considered advisable even for the comparatively small drainage areas cut off from the general drainage course by a railway embankment.

Bids were asked on the basis of using C. I. P. for all such structures. Owing to the roughness of the country over which the large and heavy pipes would have to be drawn by teams from the nearest railroad station, the contractors showed a ready willingness to substitute concrete culverts for the cast iron upon which they had bid. It was therefore decided to figure to the use of semi-circular concrete culverts of about the same capacity, with the following results:

A three-foot semi-circular reinforced concrete culvert of 4.73 sq. ft. cross section suitable for all fills up to 50 ft. could be built for $4.85 per lin. ft. ($1.00 for steel bars in place and $3.85 for concrete).

The cast-iron pipe specified for this same fill would cost $7.31 per lin. ft., and where a concrete bed would be required for it, at an additional cost of $1.70 per ft., the total cost would be $9.00 per lin. ft.

If, however, the lightest weight of 24 in. C. I. P. was acceptable to the railway company, and no concrete bed or cradle required beneath the pipe, still the pipe culvert would cost $5.69 per lin. ft. as against $4.85 for the reinforced concrete culvert.

The advantage claimed for the reinforced concrete culverts are:

1. Strength equal to that of the stronger and heavier grades of C. I. P.

2. Durability equal, if not superior, to C. I. P.

3. More than 50 per cent. greater area of water way than was provided by 24 in. C. I. P.

4. The materials of which it is built are much more easily hauled over rough country.

5. It costs only about two-thirds as much as C. I. P.

The saving over C. I. P. would be much greater for the larger sizes of culverts.

BRIDGE FLOORS.

Another use of reinforced concrete as a very important part of a railway structure that seems destined to demand greater attention in the future is found in its application to bridge floors. As municipal and state legislation becomes more and more severe and exacting on the question of grade separation, railways will be compelled to give the subject of water-tight bridge floor more attention than they have in the past. Many types of the wooden and steel bridge floors have been tried, some of them being very expensive, and, while satisfactory for a limited time, all have so far proved comparatively short lived.

Fig. 1 shows a reinforced concrete bridge floor of considerable proportions (81 x 349 = 28,269 sq. ft.) which has given perfect satisfaction during the limited time it has been under traffic (less than one year).

The advantages claimed for it are permanence or long life; small maintenance costs; superior track facilities, making it possible to have switches and crossovers at any points desired, in fact it may be made a veritable railway yard supported on plate girders; it can be made as waterproof as desired, and with the depth of ballast shown the track is easily maintained at reduced cost. Economy both as to material and labor involved in its construction amounting to from 30 to 40 per cent. over cost of steel channel floor for same purposes.

A square 10 x 10 ft. contains 3,704 cu. yds. of concrete and 718.4 lbs. of steel as built, while a standard channel floor composed of 15-in. channels protected by 4-in. gross and 1-in. net of concrete contains 1,234 cu. yds. of concrete and 2,640 lbs. of steel.

OVERHEAD HIGHWAY BRIDGES.

Overhead highway crossings as they are commonly built of wood or steel are a continual source of annoyance from a maintenance point of view.

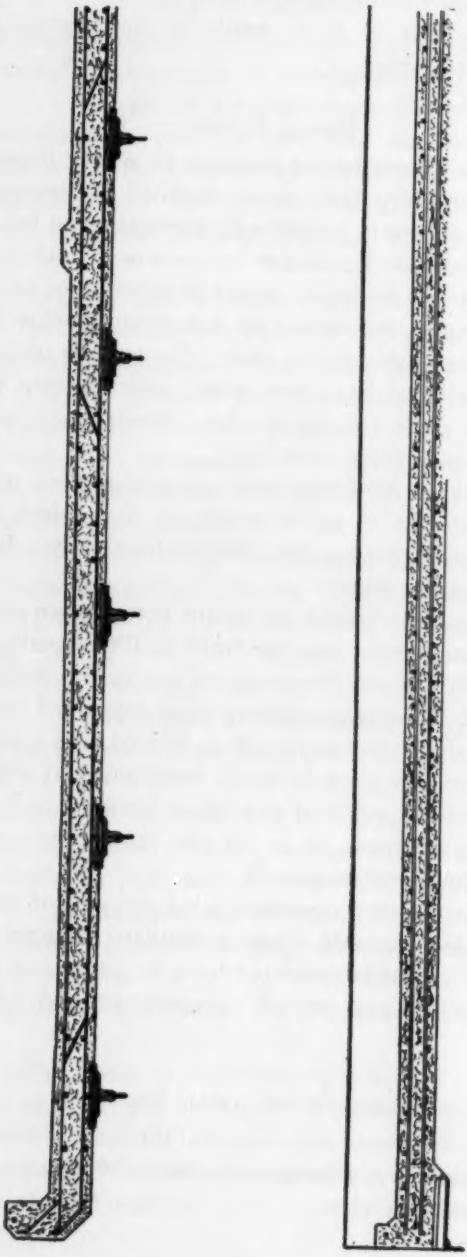

FIG 1.—CROSS SECTION OF REINFORCED CONCRETE BRIDGE FLOOR.

The sulphurous fumes from locomotives are very active, and rapidly attack all exposed steel, making protection of the best kind very necessary. Wooden floors or suspended wooden ceilings are very poor protection, and are themselves very severely attacked by the destructive agencies that they are intended to keep from the steel. They also rot out quite rapidly.

Added to these unavoidable disadvantages comes the occasional destruction of a complete structure by fire. This is by no means an uncommon occurrence on railroads, and usually structures in rural districts having no fire protection are the ones destroyed in this manner.

FIG. 2.—REINFORCED CONCRETE RETAINING WALL AT BUFFALO, N. Y. D., L. & W. R. R.

Concrete is the only building material that seems absolutely unaffected by ordinary rot, rust, fire or fume corrosion, and is therefore unquestionably the best material to use in such cases. The structure can either be perfectly protected by concrete, or it can very conveniently be built entirely of concrete properly reinforced. Several roads have already profited by past experiences with the old types of construction and protection, and are now building of reinforced concrete.

An overhead crossing structure built entirely of reinforced concrete and illustrated in sketch is thought to have all the advan-

tages in the way of permanence of construction that it is possible to obtain through the use of reinforced concrete, and very few of the disadvantages of other types of construction.

RETAINING WALLS.

Retaining walls built of reinforced concrete offer valuable economies to railways doing any considerable amount of track elevation or depression.

Walls of the section shown in Fig. 2 have proven economical and successful.

FIG. 3.—TRACK ELEVATION AT CHICAGO, ILL. C., B. & Q. R. R.

Reinforced concrete retaining walls in connection with overhead highway crossing structures make a splendid combination for ordinary track depression in suburban districts.

TRACK ELEVATION.

In the case of track elevation there is no part of the problem that cannot be worked out very satisfactorily in concrete. The retaining wall problem being practically the same in either track elevation or depression, the footings and walls are readily worked up in plain or reinforced concrete.

The structure supporting the ballast and track can also be designed of the same materials, as has been so well illustrated

by the track elevation of the Chicago, Burlington and Quincy and the Illinois Central railways in Chicago. (See Fig. 3.)

The long span slabs were 2 ft. 10 ins. thick, by 6 ft. 6 ins. wide, and were 25 ft. over all, weighing from 30 to 35 tons each. (See Fig. 4.) They were cast in the railway yards and allowed to season, then were lifted on flat cars by special crane, or ordinary wrecking engine, and deposited in place by same machine. After being thoroughly waterproofed, ballast and track were laid upon them, and they were at once ready for traffic.

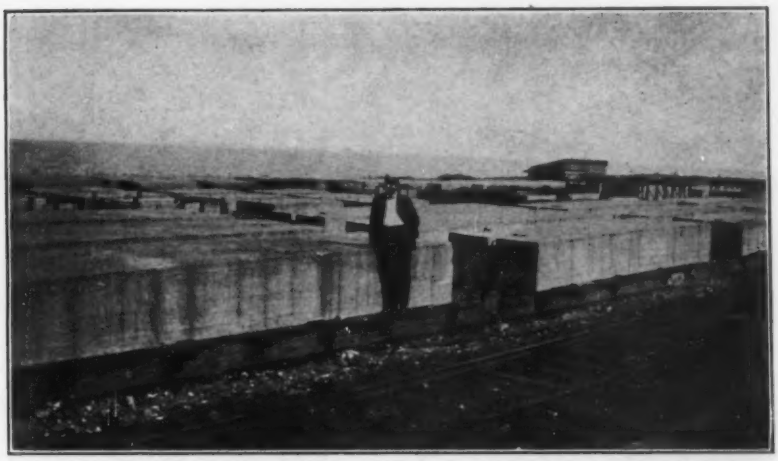

FIG. 4.—REINFORCED CONCRETE SLABS FOR TRACK ELEVATION AT CHICAGO, ILL.

COAL TRESTLES, BINS AND STATIONS.

Coal trestles, coal storage bins, and coaling stations have long been built of reinforced concrete, and are steadily growing in popularity wherever they have been tried.

A retail coal pocket and a power house coal trestle and storage pocket are shown in Fig. 5.

Grain elevators are often considered railway structures, and as such are best built of reinforced concrete. When properly constructed, they are absolutely proof against fire, water or dampness, decay, dust and vermin. Where grain has to be

stored for any considerable length of time, these are the important and essential qualities of the ideal grain elevator. A number of railroad companies have shown their appreciation of these excellent qualities by building their elevators of reinforced concrete. The Pennsylvania and Baltimore and Ohio railways have enormous elevators of this kind at Baltimore, Md. (See Fig. 6.)

The Western, Northwestern and Canadian railroads have also been quick to see and appreciate the superiority of reinforced concrete over all other building materials for this class of structures.

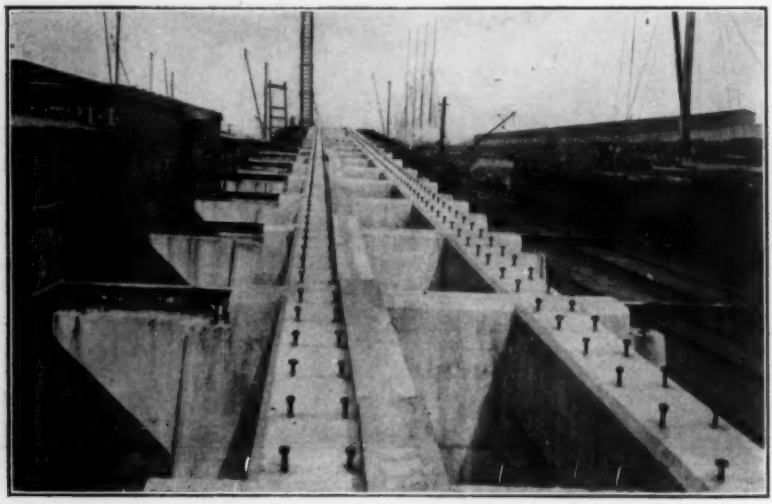

FIG. 5.—REINFORCED CONCRETE COAL TRESTLE.

DOCKS.

For railways owning valuable water front, and most railways do own some property of this kind, the question of dock construction is an important one. Owing to the great danger from fire, reinforced concrete again affords ample protection, inasmuch as the entire dock from the cut off of piles may conveniently be built of this material.

Fig. 7 shows the first of a series of piers to be built on the same general scheme along a railway yard ship canal. A typical

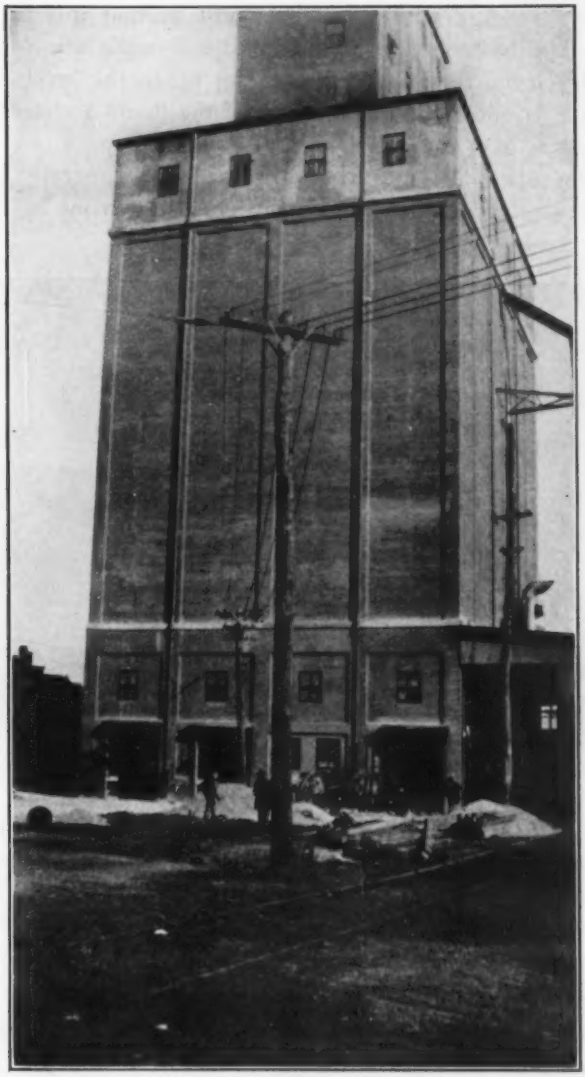

FIG. 6.—REINFORCED CONCRETE GRAIN ELEVATOR AT BALTIMORE, MD. B. & O. R. R.

cross section is shown in Fig. 8. The piles are first capped and floored over, then the heavy sea-walls of concrete, reinforced against shrinkage and shock, are built around this large platform. The footings for columns and side walls are also started from this level, then the cinder filling up to the level of tracks and floors is put in, and in the case of the floors a concrete pavement is laid over the entire area.

The side walls and roof are made of concrete, the only exposed steel being the I beam girders and purlins of the roof,

FIG. 7.—REINFORCED CONCRETE PIER.

which might also have been protected, if further protection had been deemed necessary. This pier is divided transversely by a 12-in. concrete fire wall.

STATIONS AND TERMINALS.

Railway stations, train sheds, and terminals built entirely of concrete are not at all uncommon. Some very handsome stations have been built entirely of reinforced concrete in competition with other building materials. (Fig. 9.)

The very extensive use of reinforced concrete in the new terminals of the Hudson tunnels, the Pennsylvania, New York

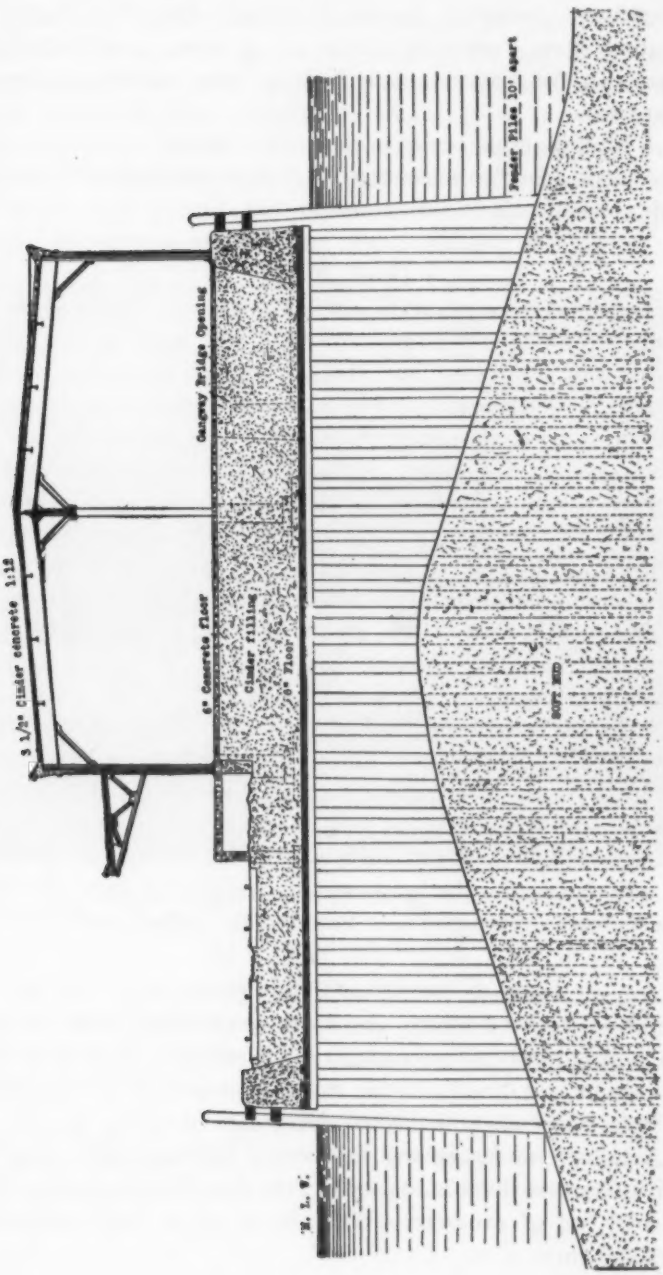

FIG. 8.—TYPICAL CROSS-SECTION OF CONCRETE PIER AND SHED.

Central, and Delaware, Lackawanna and Western railways in and about New York City, shows the growing favor with which railways in the East are now looking upon reinforced concrete construction.

A typical signal tower is shown in Fig. 10.

A good place to make use of the compressive strength and weight of concrete is illustrated in Fig. 11.

TRAIN SHEDS.

The Bush type of train shed was recently adopted by the Chicago and Northwestern Railroad in their new Chicago terminal and illustrates the extensive use of reinforced concrete involved in such construction, and the consequent economies from the maintenance standpoint. No steel is in any way exposed to locomotive fumes, which always limited the life of the old type of train shed. The roof and smoke duct are built entirely of reinforced concrete. Locomotive gases are discharged directly into the open air, much to the improvement of the atmospheric conditions in the shed and the comfort of the passengers.

The shed is always light and airy, being free from all offensive odors, and the extreme heat usually prevalent in large terminals during the summer months.

In the Hoboken Terminal train shed of the Delaware, Lackawanna and Western Railroad an additional use of reinforced concrete is made in the platforms themselves, which consist of a regular system of girders, beams and slabs. This was necessary because the shed was built entirely on "made" ground with very soft bottom. The columns, platforms and even the fence between tracks rest upon pile foundations capped with concrete.

SUBWAYS AND TUNNELS.

Subways and tunnels are most conveniently and satisfactorily built entirely of concrete or lined with it. The track itself may even be laid directly in the concrete proper, as it is in part of the Hudson tunnels under North River.

A tunnel for heavy and fast steam railway traffic that may be of interest is illustrated in Fig. 12, showing the entire lining and road bed of concrete, which should prove very economical in maintenance.

The old Lackawanna tunnel through Bergen Hill is lined with brick for a part of its length, yet fourteen men are employed every night in the year inspecting the tunnel and repairing the track, which is very difficult to maintain on account of the extremely heavy traffic. Three workmen have lost their lives at this work within the last few years. In the new tunnel this expensive and dangerous maintenance work, costing approximately $6,000 annually, will be almost entirely eliminated.

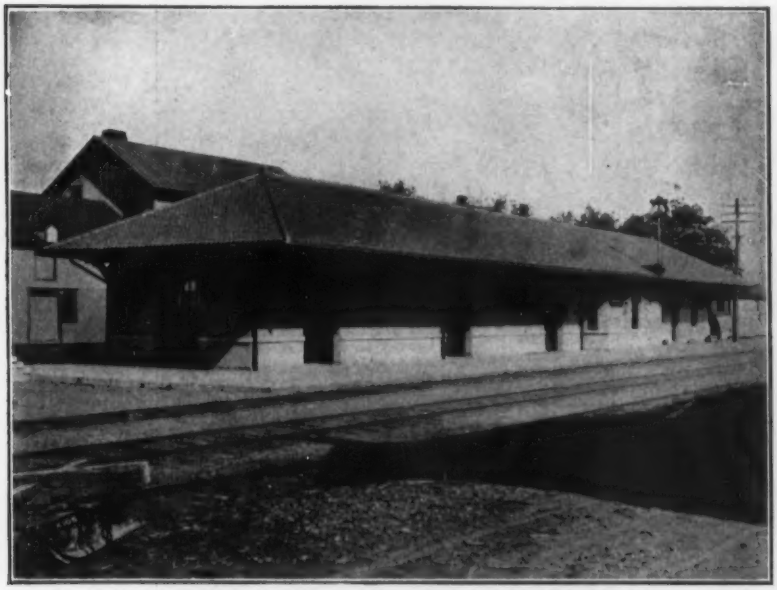

FIG. 9.—REINFORCED CONCRETE RAILROAD STATION.

ROAD BED AND TRACK.

If this type of road proves efficient and satisfactory on a solid rock foundation, experiments should be made with it in cuts and on well-settled earth fills—where it may have a great future.

As so many of the better railroads now have their lines perfectly ballasted with good clean broken stone or gravel, it is but natural to see how readily these could be converted into first-class concrete.

Elevated structures, subways and tunnels where track is thus laid directly in the concrete, should furnish the earliest reliable data on this point.

FIG. 10.—REINFORCED CONCRETE SIGNAL TOWER AT HOBOKEN, N. J.

SHOP AND WAREHOUSE BUILDINGS.

All the advantages enjoyed by the ordinary reinforced concrete building over like structures built of steel and wood are enjoyed by the reinforced concrete shop and warehouse buildings for railway purposes.

The chief advantage lies in their fireproof quality, but the greatly reduced insurance rates obtainable on such buildings and the economy in first cost when these structures are of such size, and are designed for loads heavy enough to render economies in first cost possible, are the arguments that usually decide the question in favor of the reinforced concrete structure.

BRIDGES AND VIADUCTS.

The arch bridge or viaduct seems destined to become the most important of all railway structures that can be built to

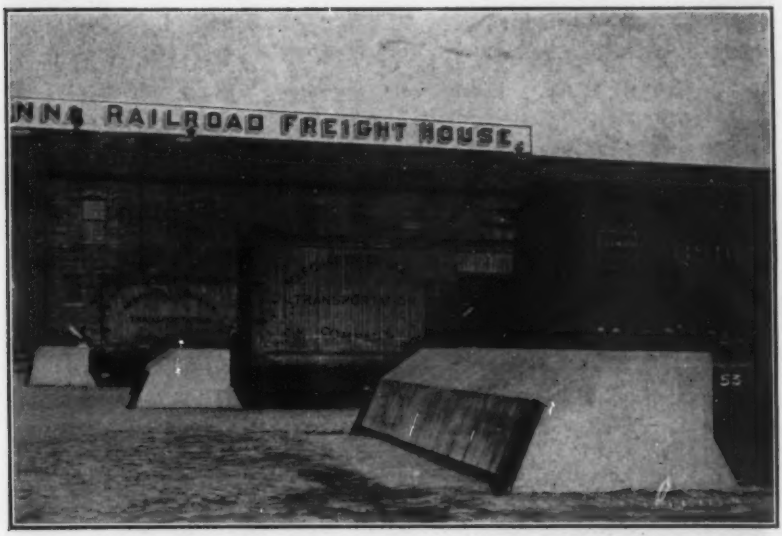

FIG. 11.—REINFORCED CONCRETE BUMPING POSTS.

advantage of plain or reinforced concrete. Not only is the arch with proper foundations the most enduring type of structure that can be built, but it is also a thing of beauty, and its maintenance costs are practically nothing during its entire period of usefulness.

The old stone masonry arch had many fine qualities to recommend it, but it also had its limitations. In fact the failures of first-class old masonry structures show clearly the necessity

of reinforcement and furnish best guide to proper method of reinforcing the concrete to prevent similar failures in reinforced concrete construction.

The concrete arch has many points of superiority over the stone arch. In the first place it can be so reinforced that there will be no tension in any direction in the masonry proper; secondly, economies in yardage of masonry can be nicely worked out in concrete that would be considered inappreciable if the

FIG. 12.—VENTILATION SHAFT AND CONCRETE ROADBED IN NEW BERGEN HILL TUNNEL.

same plans were executed in stone; thirdly, the difficult and expensive construction of skew arch spans when built of cut stone is greatly simplified by the use of concrete. By means of system of offsets in the skewbacks and the proper distribution of a small amount of reinforcement, this skew construction is rendered simple and inexpensive.

And lastly the concrete masonry is very much cheaper per cubic yard and can be put in place much faster than stone, both

decidedly important items to consider, especially when the structure is built under traffic, or where there is a likelihood of losing the centering and structure on account of freshet.

The reinforced concrete arch or viaduct has even greater advantages over like steel structures than over stone masonry for ordinary railway spans, which may be summarized as follows:

1. A reinforced concrete arch viaduct may reasonably be expected to have a life many times that of a steel structure. A fact that may justify several times the investment necessary to secure permanent construction.

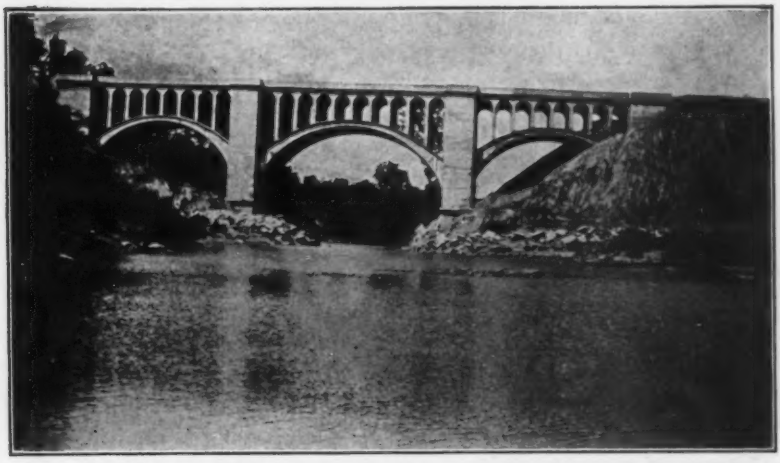

FIG. 13.—DOUBLE TRACK ARCH OVER VERMILION RIVER, DANVILLE, ILL. BIG FOUR.

2. Its maintenance costs are almost negligible. The elimination of painting alone warrants a first cost expenditure 10 to 15 per cent. in excess of the first cost of steel structure requiring paint.

3. Track is easily maintained on such a structure, ordinary track ties and ballast taking the place of the expensive bridge ties of a steel structure, thus guaranteeing a safer and better track for fast traffic, and economy in renewal of timber deck.

4. Danger of derailment is lessened, but even in case of derailment on a concrete structure the consequences would cer-

tainly be less disastrous to the traveling public, as well as to the structure itself. A derailed car or a projecting piece of heavy freight upon striking an important compression member of a steel structure has been known to wreck it or render it unsafe for traffic until repaired.

5. In riding over a structure built of reinforced concrete with a ballasted floor there is none of the attendant noise and lurching of the train as it strikes the unyielding backwalls of the bridge masonry and the steel floor of the bridge proper.

To the passenger, the absence of the familiar roar in crossing a bridge is particularly gratifying, and the visible hand railing and substantial masonry copings give him an additional sense of security, not enjoyed on most steel structures.

EXISTING AND PROPOSED ARCH VIADUCT STRUCTURES.

Probably the best way to summarize the subject of railway arch viaducts would be to review briefly representative structures on each of a number of railways using them.

BIG MUDDY RIVER VIADUCT.

The Illinois Central Railway arch viaduct over the Big Muddy River near Carbondale, Ill., was perhaps the first long viaduct of this kind to be built in this country. It consists of three semi-elliptical spans of 140 ft. each having a rise of 30 ft. The use of spandrel arches over the main arch rings gives this structure a very handsome appearance and at the same time considerably lightens the load on the pile foundations.

The structure has been under traffic about six years and has not in all that time shown any defect or weakness, neither has it cost the company one cent for maintenance.

It cost approximately $125,000.00 or about $250.00 per linear foot of its total length of 502 feet. It is a double track structure and was built under traffic.

DANVILLE ARCH VIADUCT.

The Big Four Railway arch viaduct over the Vermilion River at Danville, Ill. (Fig. 13), is another of the older struc

tures of this type that has given excellent satisfaction during the three years or more that it has been under traffic.

It contains about 12,000 cu. yds. of concrete, all of which was placed in the remarkably short time of four months. It was built and thrown open to traffic in considerably less time than it was possible to secure steel deliveries at the time of its construction. The viaduct is built on a shale foundation 95 ft. from base of rail. The structure requires no painting and its first cost was actually less than the estimated cost of a somewhat

FIG. 14.—VIEW OF LONG KEY FROM REAR PLATFORM OF TRAIN ON VIADUCT.

longer steel viaduct necessary for the same site if the latter had been used.

Unforeseen foundation difficulties increased the cost of this structure slightly, but the same conditions would correspondingly have increased the cost of a steel viaduct.

KEY WEST VIADUCTS.

The concrete construction of the Key West extension of the Florida East Coast Railway as originally planned consisted of about 500 reinforced concrete segmental and semi-circular arches of from 45 to 60 ft. span, and had a total length of about 6 miles.

This immense concrete undertaking was to have been divided into four separate and distinct viaducts, as follows:

1. The Long Key Conch Key viaduct 10,500 ft. long,
2. The Knights Key Channel viaduct about 7,800 ft.,
3. The Moser Channel viaduct about 7,300 ft.,
4. The Bahia Honda Harbor viaduct about 4,950 ft., composed entirely of 60 ft. arches.

Arch rings of the first viaduct are 15 ft. wide and 2 ft. thick at crown and are 4 ft. 6 ins. thick at tops of piers. The piers

FIG. 15.—LONG KEY VIADUCT AS SEEN FROM THE EXTREMITY OF LONG KEY DOCK.

themselves are 21 ft. long and 7 to 12 ft. in width, every fifth pier being considerably wider than the others to act as an abutment during construction and as a protection to structure in case of the destruction or failure of one or more adjoining spans.

Up to the present time only one of the four viaducts has been completed.

The Long Key viaduct, consisting of 183 fifty-foot semicircular arch spans, is the longest structure of its kind ever built. It was constructed as a monolith from end to end and under the favorable climatic conditions of southern Florida, no tempera-

ture or shrinkage cracks are visible except under the closest inspection. Such cracks as have developed, in the coping mainly, are very minute and are so few and far between that they are not considered dangerous or even objectionable. Figs. 14, 15, 16 and 17 illustrate this viaduct.

Work upon the three remaining structures is now being pushed to completion as rapidly as possible. In order to get this road in operation to Key West at the earliest possible date and also to reduce first cost to a minimum, the superstructures of

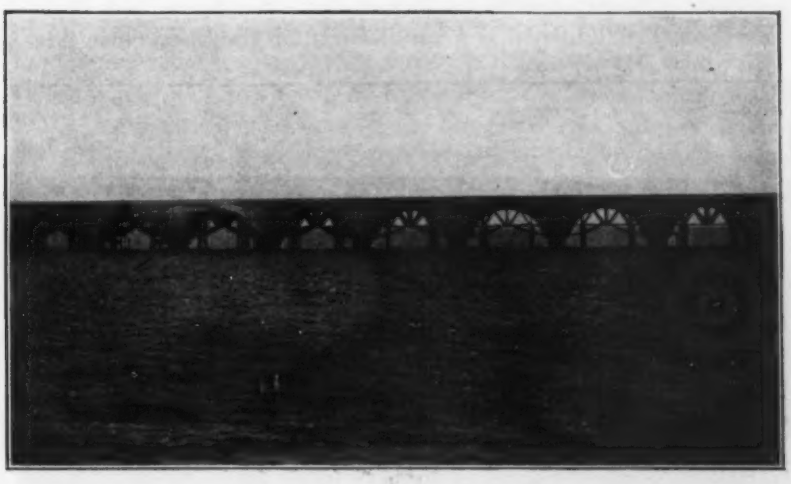

FIG. 16.—VIEW OF LONG KEY VIADUCT WITH CENTERING IN PLACE.

the remaining viaducts will be of steel (plate girders and through trusses), resting upon reinforced concrete piers. The lengths of the several viaducts are also considerably changed according to the new plans.

SANGAMON RIVER VIADUCT.

The Wabash Railway recently built a reinforced concrete arch viaduct over the Sangamon River near Decatur, Ill., that deserves more than passing mention. It is built on a skew of 45 degrees and has very novel skeleton abutments, each consisting of two side walls, and connected by two horizontal cross slabs

or diaphragms, on the upper one of which track and ballast is laid for traffic, the lower slab acting only as a tie between the two vertical sidewalls.

This structure cost $117,000.00 approximately or only $191.00 per lin. ft. of double track viaduct.

It replaces a steel structure composed of one 158 ft. truss span, two 116 ft. truss spans and two 40 ft. plate girders erected in 1885. Time of building the concrete structure was one year.

PAINESVILLE ARCH.

The Painesville arch viaduct of the Lake Shore and Michigan Southern Railroad is a handsome four track structure hav-

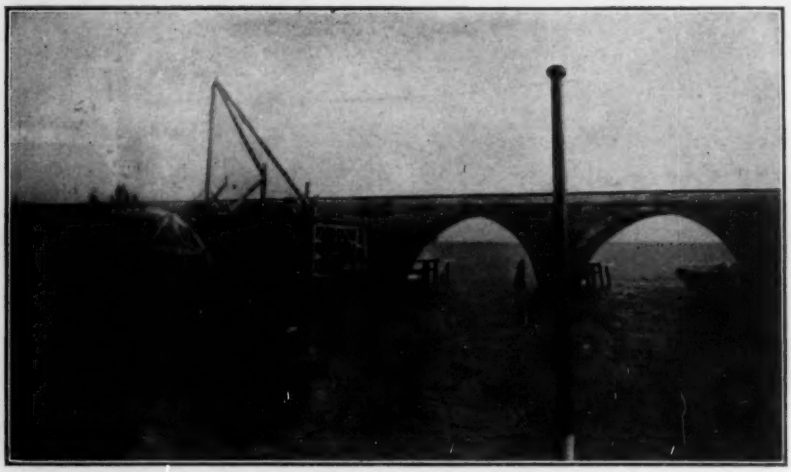

FIG. 17.—STRIKING CENTERS UNDER LONG KEY VIADUCT ARCHES. (Some centers had to be jacked down after wedges were completely withdrawn.)

ing a channel span of 160 ft. at each end of which there is an 80 ft. semi-circular approach span. This structure has been under traffic but a few months. The main arch with its 160 ft. clear span and 56 ft. 3 ins. rise gives this viaduct the distinction of containing the longest span railway arch in this country.

NOTES ON EUROPEAN CONCRETE VIADUCTS.

European engineers have found plain concrete arches of the three-hinged type very economical for railway structures. Much

longer spans have been built there than American engineers have yet attempted.

Two very handsome structures of this kind at Kempten, Bavaria, one a double and the other a four-track structure, have channel spans of 211½ ft. each. The total cost of these structures as given by the Engineering Record, Vol. No. 55, No. 19, was only 1,156,000 marks, showing a saving of 264,000 marks, or 22.8 per cent. over estimated cost of steel structure for same sites.

A single track viaduct containing a channel span of 187 ft. over a tributary of the Danube at Lautrach, also in Bavaria, affords another interesting example of European railway practice. This structure, according to the authority before quoted, cost only 91,000 marks, or approximately $18,200, while the estimated cost of a corresponding steel bridge was 110,000 marks. Based upon the above figures and the total length of viaduct including approach spans, this structure cost approximately $66.50 per linear foot of single track structure. The use of concrete in this case made possible a saving on first cost alone of 20.9 per cent. over that of a corresponding steel structure.

CONCLUSION.

In the foregoing discussion of the uses and advantages of reinforced concrete for railroad construction, no attempt has been made to include all of the uses of reinforced concrete in railway construction, or even to be complete in the discussion of any one subject. Reinforced concrete ties, telegraph poles and other equally important and interesting subjects could not even be mentioned. The facts have been roughly pointed out and in most cases as briefly stated as was consistent with clearness.

In conclusion, let it be clearly noted that reinforced concrete construction, while usually cheaper in first cost than the other building materials, in all the cases above cited, has certain structural and physical advantages that would amply justify its use even though its cost were very much in excess of the costs of other types of construction.

CONCRETE PILES—FORMS, ADVANTAGES AND COST AS COMPARED WITH WOODEN PILES.

By C. W. Gaylord.*

In taking up the subject of the comparative cost of wood and concrete piling and further discussing the various forms of concrete pile construction as it is practiced in America to-day, this paper will be confined to foundation piles, especially those under buildings and to the most widely known of the concrete pile systems. The phase of the subject pertaining to reinforced concrete piles in wharf and dock construction will not be touched upon, nor the special forms of concrete piles adapted to peculiar subsoil formation. In discussing the comparative cost based on actual work done, it is only fair to omit the subject of wharf and dock work where concrete piles have had little chance to prove their utility and confine the discussion to building foundations where concrete in open competition with wood has had such a remarkable success in the past few years. Before, however, taking up the comparison of cost, let us consider the history of concrete piling and explain the several prominent systems which are structurally adapted to varying conditions and have been used successfully.

As with many other forms of concrete or reinforced concrete construction, concrete piles were first used abroad, although now American methods are superior and are meeting with considerable interest and general approval throughout Europe. Hennebique was the first engineer to use reinforced concrete piles. Since 1896 he has designed and driven many forms of "made-up" piles for both bearing and sheet piling purposes. The pile generally used by Hennebique is 12 ins. square in section reinforced at the corners with four round bars about 1 in. in diameter and held together with heavy iron wire tires about every 8 ins. Figs. 1 and 2 illustrate the manufacture and driving of this type of pile.

*Chicago, Ill.

Since the introduction of the Hennebique pile there have been many different forms of the made-up reinforced concrete

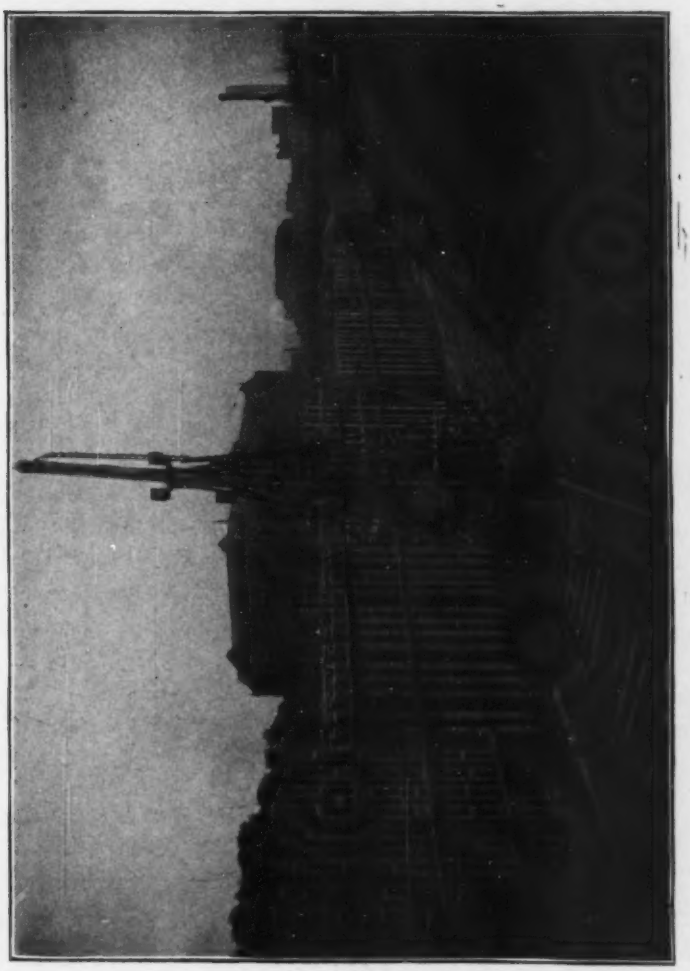

FIG. 1.—HENNEBIQUE REINFORCED CONCRETE PILES.

piles used abroad, and all the development has been along these lines. It is, however, unnecessary to discuss further the European methods, as the situation there is far different from what

it is here. There the extremely high price of wood piling has allowed favorable competition with the expensive made-up reinforced concrete pile, and the engineers have lacked the incentive that has brought out and perfected our cheaper methods. To illustrate this point, take the reinforced piles in Southampton Harbor, England. To reproduce these here, under similar circumstances, would cost nearly $3.00 per lineal foot. This brings us to the introduction of concrete piles in America.

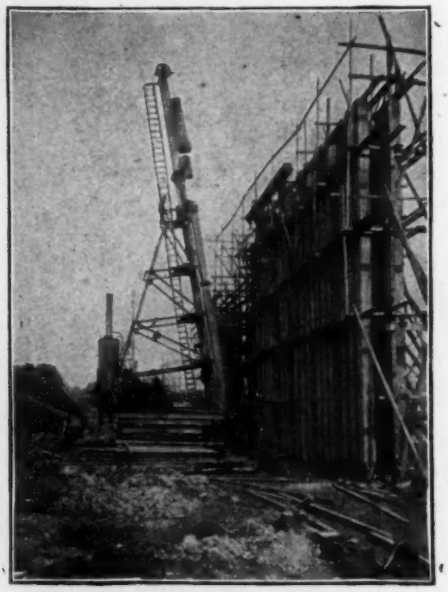

FIG. 2.—DRIVING HENNEBIQUE PILES.

In 1901 A. A. Raymond, of Omaha, the inventor of the Raymond system, was the first to awaken the American engineering world to the possibilities of concrete in the form of piling. The Raymond system was a radical departure from any of the European methods, all of which, omitting one minor exception, were developed along the line of the made-up pile, which had to be cast first and then driven like a wood pile after the concrete had set. Mr. Raymond devised a system by which he was able to mold the pile in place.

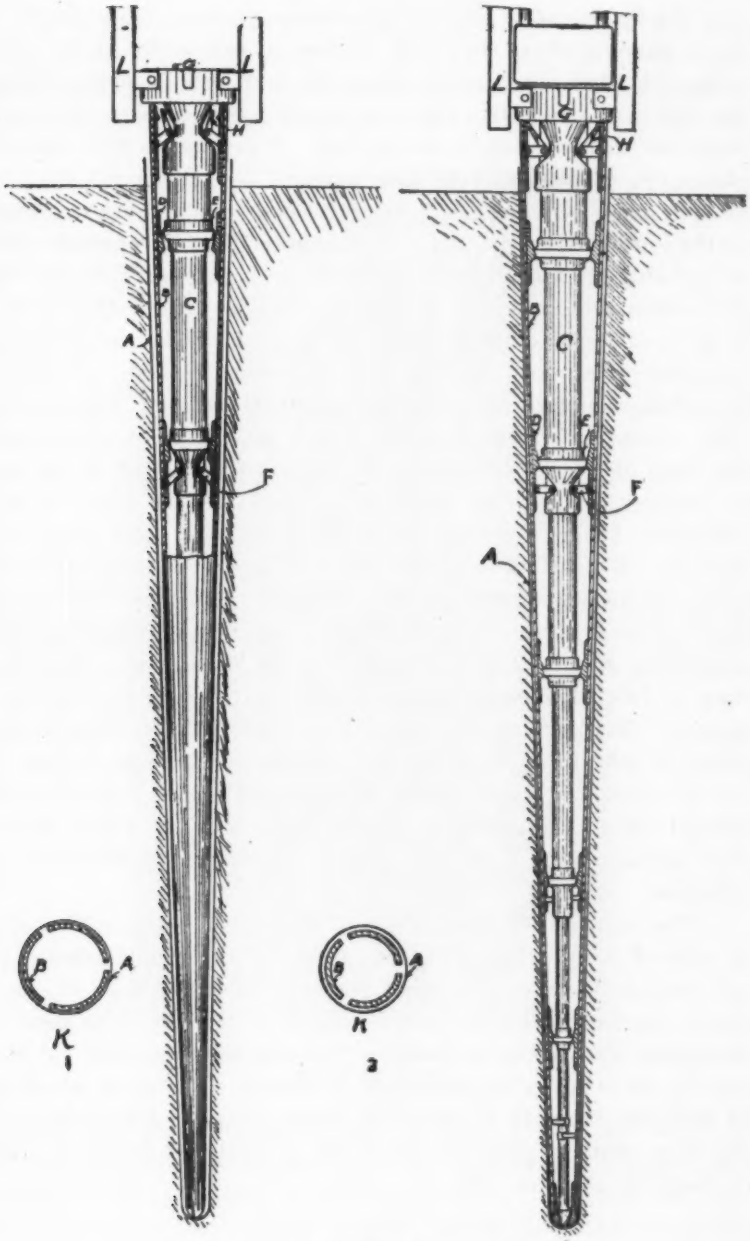

FIG. 3.—RAYMOND CONCRETE PILE.

Briefly described, Raymond concrete piles are made by driving a tapering sheet steel shell or pipe to refusal by means of a collapsible steel core, withdrawing the core and thereupon filling the shell with concrete. Fig. 3 shows this style of pile. A represents the shell, driven in the ground. B represents the exterior plates (¾ in. thick) of the pile core. C represents the stem of the pile core, made of extra heavy pipe of diminishing diameter as the lower end of the pile core is approaches. D represents the wedge-shaped castings fitted to the exterior plates. E represents the corresponding wedges fitted to the interior stem. This wedge is made of a steel casting, which also acts as a collar for coupling together the various sizes of pipes forming the stem. F represents hinges linking the exterior plates and interior stem of the core. Note their position when core is expanded. G represents the head of the core, made of cast steel hollowed out at the top to receive an oak cap block, which receives the blow of the hammer. H, keys to keep the exterior plates in place when expanded. K represents cross section, showing opening between plates to allow for collapsing. L, steel leads of driver. Left hand sectional view of Raymond pile core, shows collapsing and expanding device. (Steam hammer in the leads resting upon the core.) In this illustration the shell is driven and the core expanded. Right hand sectional view of pile, core collapsed and ready to withdraw from the shell. Note that wedges D and E are no longer in contact, thus allowing the plates B to collapse toward center of core, leaving a space between plates B of core and shell A. Note also position of hinges F when core is collapsed.

The sections overlap sufficiently to exclude any soil, water or other foreign substances that might otherwise gain admission into the shell while it is being placed. After the core is completely encased in the shell, it is driven to refusal. The core is thereupon withdrawn by bringing the segments together, or collapsing the core, as the operation is termed. The shell, which is of sufficient strength to retain its shape after the withdrawal of the core, remains permanently in the ground and forms a mold or form for the concrete.

The particular advantages claimed for this system are that with the use of a steel shell there is a form for every pile which absolutely protects the concrete until it has fully set and in every case assures a pile that can be easily inspected; that, on account

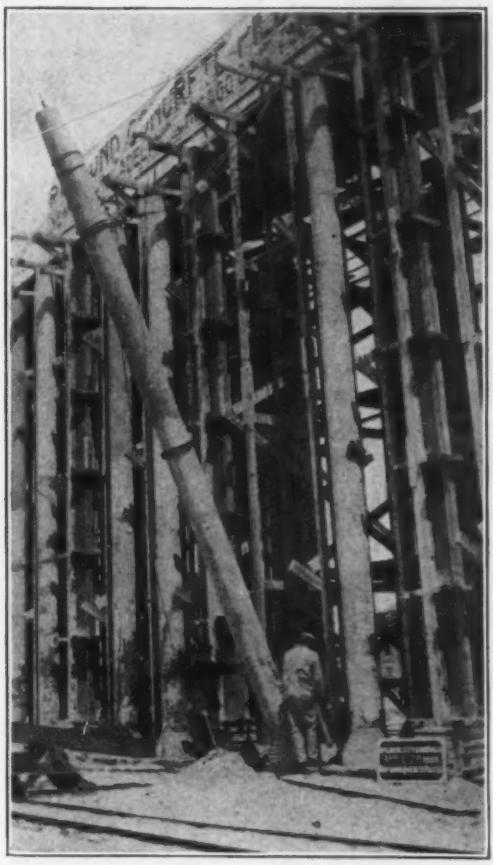

FIG. 4.—PILES FOR ATLANTIC CITY BOARDWALK.
RAYMOND PILES.

of tapering shape and the increased diameter that can be given to the core, a great increase in bearing power is obtained and much shorter piles may be used than when a pile without taper is driven, and that, further, the steel core can be driven to refusal

or a penetration not to be thought of with a wooden pile and the full bearing power of the soil developed beyond a doubt. Concrete foundation piles are as a rule not reinforced, but this can

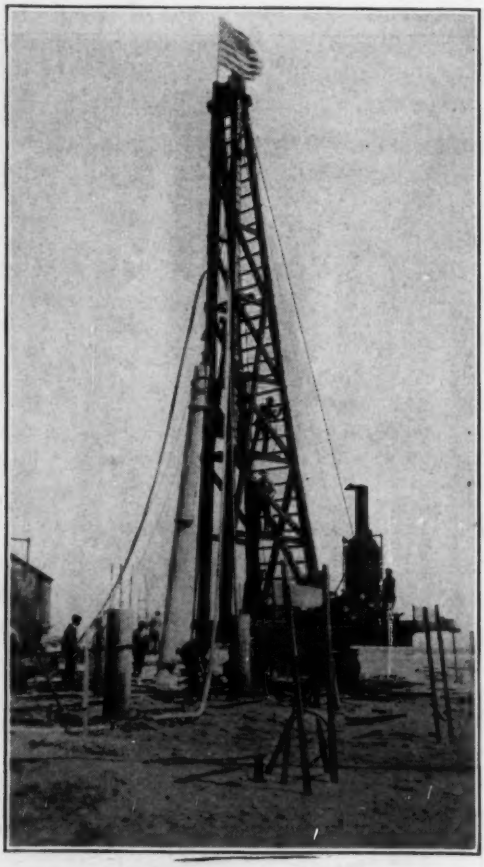

FIG. 5.—DRIVING PILES AT ATLANTIC CITY, N. J.
RAYMOND PILES.

easily be done, as, with the core withdrawn, the placing of reinforcement and concrete is nothing more or less than column construction.

The Raymond piles are driven with the ordinary pile-driving outfit, with the addition of a few changes to adapt the core to

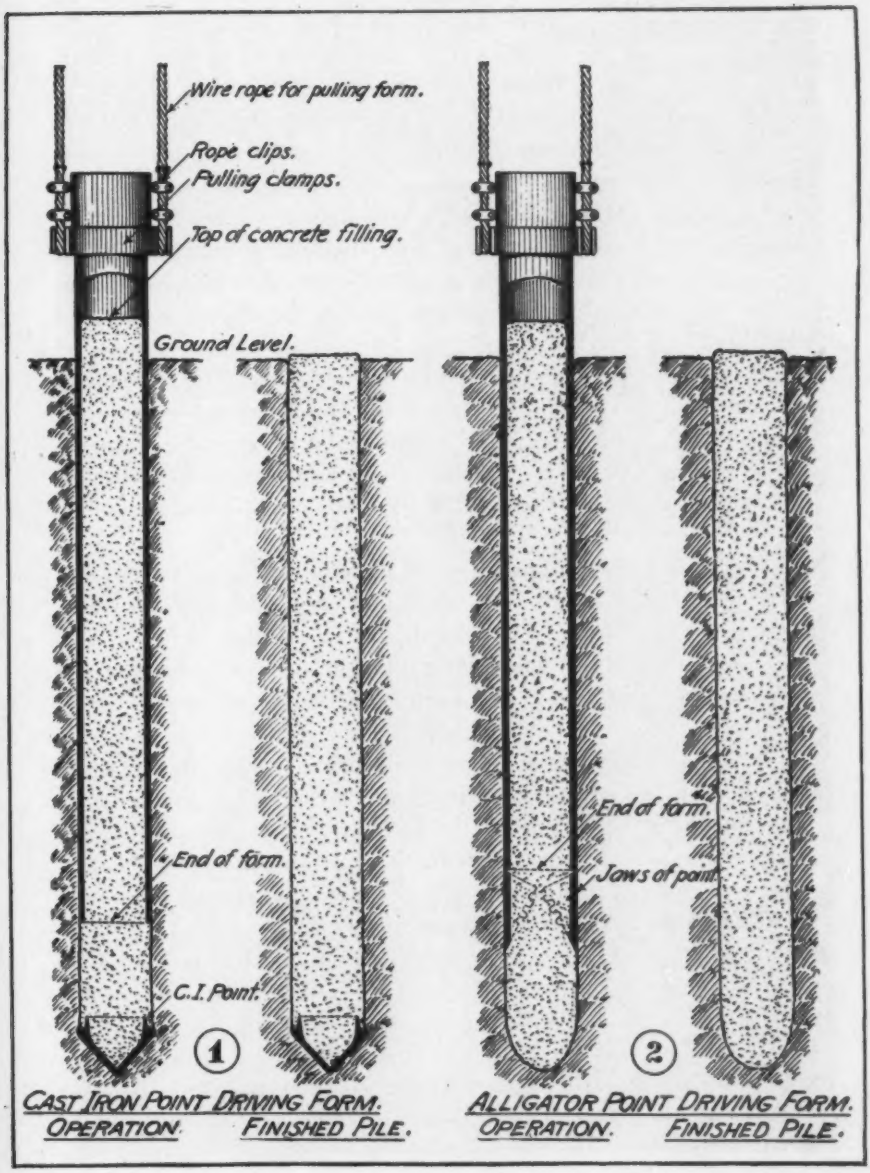

FIG. 6.—STANDARD SIMPLEX CONCRETE PILES.

the leads, etc. Considerable speed can be maintained in driving them, as over forty piles have been driven in a day. Fig. 4 shows piles for the Atlantic City Boardwalk, and Fig. 5 illustrates the method of driving.

In 1903 Mr. Frank Shuman, of Philadelphia, patented the Simplex system, which is another type of concrete piling molded in place. In addition to the general advantages of concrete piles, the particular claim made by the Simplex Company is that by ramming the concrete is driven into the surrounding earth and the bearing power of the pile greatly increased by the increasing of the frictional resistance of the sides; that the large size of pipe used for driving compresses the earth far in excess of what can be done with the largest wooden pile now used; and that any advantages to be had from the bearing of the substrata directly under the point is utilized by keeping the diameter of the pile uniform. The Simplex pile can be reinforced, although this is not generally done with the ordinary foundation piles. Fig. 6 illustrates this type of pile.

About 400 to 500 lineal feet of piling is given as an average day's work for a single pile driver and crew, although as many as 31 piles 30 ft. long have been driven in one day.

Since 1903 there has been a number of new inventions in the concrete piling field, and some very ingenious devices have been made to meet obstacles which have presented themselves. These new systems have all been developed along the lines of the made-up pile, being cast first and driven like a wooden pile or jetted after the setting of the concrete. The most known of these new types are the Gilbreth, the Chenoweth and the Cummings. Briefly stated, they are as follows:

The Gilbreth pile is a corrugated tapering concrete pile reinforced with Clinton electrically welded fabric ⅜ in. wires, 3 ins. on centers longitudinally with ⅛ in. wires, 12 ins. on centers around the pile. The pile is made as an octagon, tapering from 16 ins. in diameter at the large end to 11 ins. at the point, with corrugations running the entire length of each side. The pile is tapered so as to develop the full bearing power of the soil throughout its entire length and the corrugations are added to increase the surface skin friction and also to form outlets for the water from

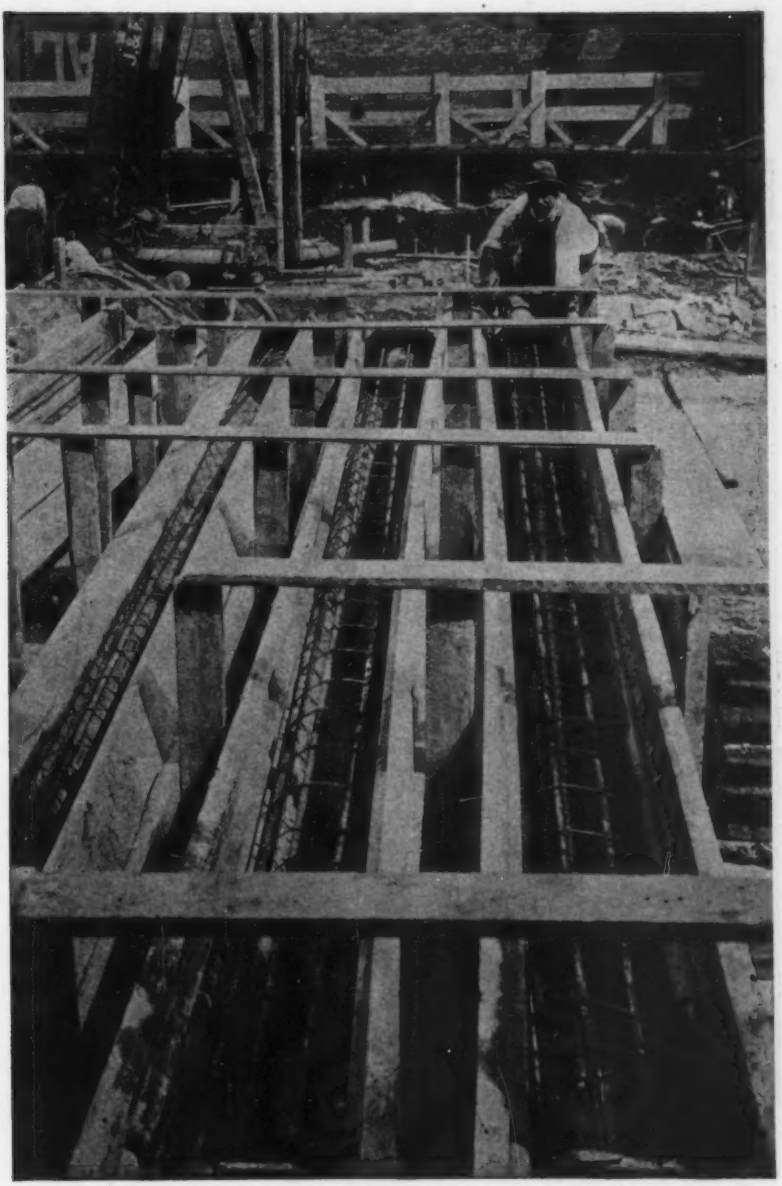

FIG. 7.—REINFORCEMENT FOR GILBRETH PILE IN PLACE, READY FOR CONCRETE.

the jet. There is a hole through the center of the pile formed by a plug tapered from 3 to 2 ins. in diameter for ease in removing. The piles are cast in wooden forms and carefully cured for 30 days. They are then handled by an ordinary pile driver and

FIG. 8.—TURNING FORMS DURING CONCRETING TO ELIMINATE AIR POCKETS. GILBRETH PILE.

jetted into place by running a 2 in. jet pipe through the hole in the center of the pile. The weight of the hammer resting on the special driving cap which covers the head of the pile and

helps push the pile down into the hole made by the water jet. The special driving cap consists of a steel shell with wooden blocks at each end and pieces of hose and rope in between to form a cushion. When the pile has been jetted nearly into place, the hammer and cushion cap are hoisted and the jet removed, the cushion cap replaced and the pile driven to the desired penetration. Figs. 7, 8, 9 and 10 illustrate the Gilbreth pile.

The Cummings pile is another type of made-up reinforced concrete pile, octagonal in section and of any length up to 60 ft.

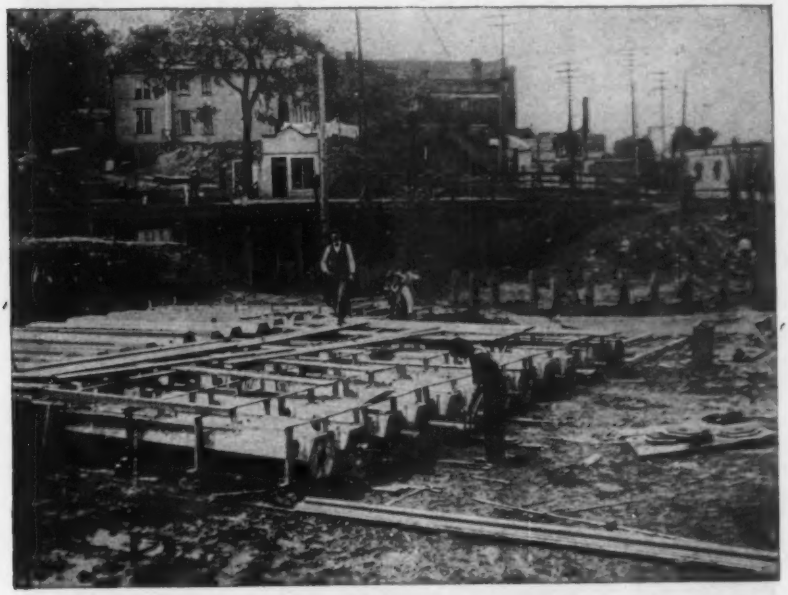

FIG. 9.—GILBRETH PILES IN STORAGE.

Except when driven to rock this pile is tapered to gain additional bearing power and is reinforced as follows: There is a short section of electrically welded hooping at the top and bottom of the pile, and between these two points spiral flat hooping is used. The longitudinal reinforcement is composed of steel angles. The pile is also equipped with a malleable iron shoe, which is riveted

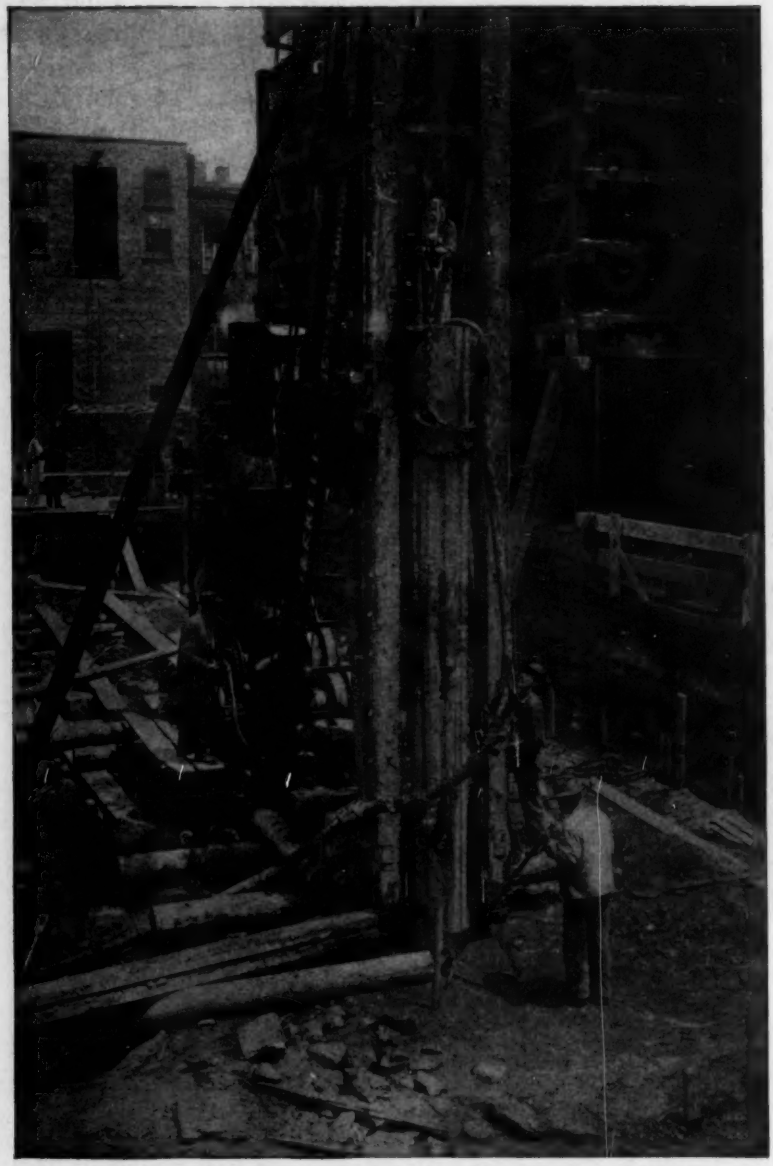

FIG. 10.—GILBRETH PILE IN PLACE READY FOR CAP AND DRIVING.

to the reinforcement. The reinforcement, however, is in each case designed for the particular work. The top of the pile is protected when driving by a cast steel sleeve with guide lugs. This sleeve may be attached to it or it may form an extension of the pile head for receiving the resilient medium to cushion the direct blows of the steam or drop hammer. The Cummings pile is driven or jetted into place like a wooden pile. They have been tested in the same manner as the other concrete piles and have carried as much as 41 tons without settlement and 63 tons with

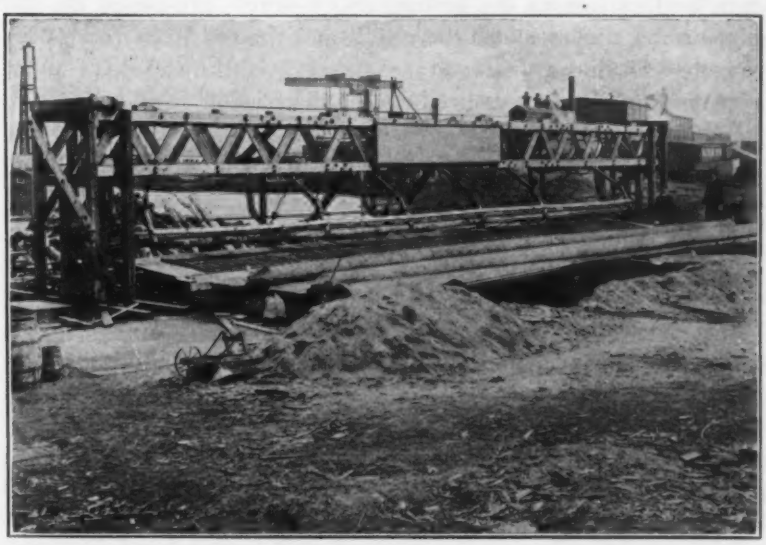

FIG. 11.—CHENOWETH MACHINE FOR MANUFACTURING REINFORCED CONCRETE PILES.

only ½ in. settlement. Generally 1:2:4 concrete is used in the construction of this pile.

The Chenoweth pile is still another type of reinforced concrete pile cast before driving. This pile is round and is made without forms on a special apparatus and is reinforced with a steel pipe or rod in the center, a coiled sheet of wire netting and longitudinal steel rods placed near the perimeter, equal distances apart.

The apparatus for rolling the pile consists of traveling platform and roller between which the pile is formed, see Figs. 11 and 12. The winding pile or rod in center is set in line of the shaft of the large spur wheel shown. In operation the steel wire netting with the longitudinal rods attached is spread on the platform and covered with a layer of concrete, C, Fig. 12. One edge of the netting is attached to the edge of the platform, and the other edge to the winding pipe or mandrel. Thus arranged, the winding mandrel is rotated and the netting and its covering of concrete is wound or coiled up as in D, Fig. 12. At the same time and as fast as the netting and concrete are coiled up, the platform A moves under the roll B and the roll itself rotates.

The forming cylinder of concrete is by this means kept under constant and heavy pressure between the platform and roller. To

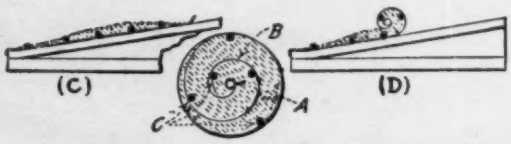

FIG. 12.

bind the roll of concrete wires are wound around it at close intervals and tied. The wires are contained on spools arranged beneath the moving platform. These spools are spaced every 6 ins. along the pile and fastened to the wire mesh, so that when the pile reaches the lower edge of the platform it can be revolved about the axis, causing the wire to be wound on the pile. In this manner the wire is passed around the pile a number of times and secured. At the driving end of the pile the spools are placed 4 ins. apart for the first 6 ft. of the pile and then 6 ins. apart for the remainder of its length. The pile is removed from the machine by rolling on to a car, when it is transported to a platform where the point is formed, flushed up or smoothed, if desired, and allowed to remain until it hardens.

A driving cap is used, consisting of a cylinder of steel with a diaphragm midway between the ends. This is placed on the pile with a coil of rope as a mat below diaphragm, sawdust and a wooden follower block.

It is claimed for the piles that when reinforced as described they are able to withstand any rough treatment in handling and driving. The bearing capacity is four times greater than that of a wooden pile. A pile 61 ft. long, 13 ins. in diameter, can be suspended in the middle, dropped from platform, rolled down an embankment and driven in the hardest kind of material. These piles show a remarkable degree of elasticity. Chenoweth piles are driven with an ordinary wooden pile driver with extra heavy hammer. The concrete used is generally 1:2:3 mixture.

In discussing a comparison of wooden and concrete piling, the basis of cost is generally the final grounds on which the prospective user makes his decision. And keeping both forms of piling within good engineering practice, cost is a very fair basis of comparison. Let us now consider those features of a good piling foundation which are absolutely essential and which govern the cost. First, the foundation must carry without settlement the load of the superstructure. Second, it must be permanent. And third, it must be placed with despatch in order to save rent, interest, etc., during the construction period. These are the three main features in considering a foundation. There are others, of course, but they are minor ones which can either be neglected or affect the cost of both concrete and wooden piling alike. In taking up the first feature mentioned, we assume that the load is the same for the both types of piling and, therefore, that the same bearing power must be developed in each. Our first problem then is to determine the relative cost of a concrete pile as compared with the cost of sufficient wooden piling to develop the same bearing power.

In discussing a subject of this nature, it should be understood that any statements made must be rather broad and that local conditions may change the conclusions reached completely. I choose this method in preference to giving the exact data on one or two jobs, which are invariably misleading on account of these same local conditions. I shall assume average basis for comparison and explain as I go along the local conditions that might or would change this basis. In general, then, let us assume that, per lineal foot, concrete piles will cost four times as much as wooden piles driven under the same conditions, that

in 90 per cent. of the soils encountered the necessary length of the wooden pile is about 50 per cent. longer than the concrete pile and that the load carried by a concrete pile can be safely doubled over that of a wooden pile.

In making the first assumption, the ratio of cost is based on a number of different cases, and since wooden and concrete pile driving is essentially the same operation and as the local conditions, which affect the actual pile driving itself, influence both to practically the same degree, this ratio remains the same under varying conditions. The local conditions that do affect the cost are the cost of materials themselves, and this must always be taken into consideration if varying much from the general average.

The assumption that shorter and fewer concrete piles can be substituted for wooden piles is explained by the fact that greatly increased bearing power can be obtained by using the shape best adapted to develop the bearing power of the soil in question, and as the concrete pile supported by the earth on all sides is good for practically the safe load that the area of its head will hold, therefore, its ability to carry a load is much increased by its greater area than that of an average wooden pile.

Take for example the 20-in. diameter head of a Raymond pile. This has 314.16 sq. ins. of head surface—nearly as great as that of three 12-in. piles or over that of two 4-in. piles. As every particular pile driving man has experienced, it is much easier to drive a slender pile with a 6-in. point than a heavy pile with a 10-in. point. Exaggerate this condition, and you have a comparison of the load-bearing capacity of the average wooden and the concrete pile. Then compare a wooden column with one of concrete of 50 to 75 per cent. greater cross section and you have the reason why a shorter concrete pile is generally good for twice the load or more of a wooden pile in the same ground. The condition of the sub-laying strata is the local condition in this case, and one that can often only be determined by the actual test of pile driving, except for places where no firm or weight-bearing strata can be found until 50 ft.; the above will hold true for all but extreme cases.

In summing up this cost of bearing power, we must conclude that under average conditions, the same bearing power

costs about 25 per cent. more when developed by concrete pile than when developed by wood piles. So far, the average would seem to lie with the wood piling, but further consideration will quickly change the scales in favor of concrete.

The second condition to be considered involves the necessity of permanency in the foundation and its effect on the relative cost. There is only one sure way known to-day to make wood piling practically permanent and that is to saw it at a point below the water line or at a point at which the pile head will be continuously wet. This means that the footings or capping which rests on the piles and carries the superstructure must go

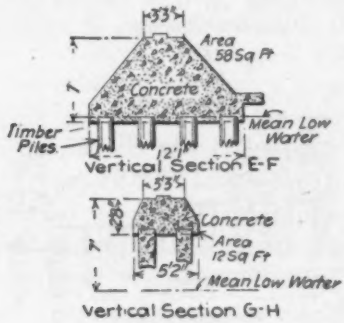

FIG. 13.

down to below the permanent water line. Here is a point where concrete pile effects a big saving, as it can be placed entirely independent of depth of the water line. (See Figs. 13 and 14.) Mr. Shuman, of the Simplex Company, states that in general, if it should be necessary to lower the footings for wooden piles only 3 ft. on account of the water line, it is cheaper to use a concrete pile. The lower the water line below the necessary depth of the cellar or basement, the greater is the saving by the use of concrete piles, for the lower the foundation footings are carried, the greater becomes the cost of these footings, and greater the cost of excavation, shoring and pumping during the construction period. With concrete piles, there is practically no excavation necessary below the basement level, except to give sufficient depth to the footings to distribute the load, and there is no

shoring or pumping. But the above is not the only consideration that must be given to the water line. When once the wooden piles have been placed, cut off and capped, then the water line must not drop below the assumed elevation or the wooden piles will surely rot. This is, indeed, a serious consideration, and one that is attracting considerable interest, especially in the large cities. In a recent communication to myself this point is covered very clearly:

You will probably be interested to know that we are constantly securing contracts for concrete piles under conditions where wood piles could be placed at the same or lower cost and placed below the present water level, preference being given to concrete piles, because of the fact that water levels are constantly changing in all the cities, due to deeper

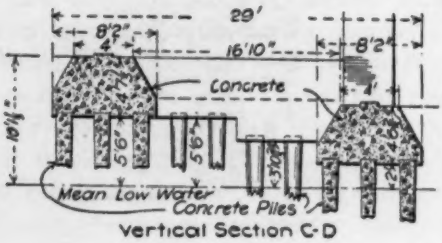

FIG. 14.

sewers, freight and passenger subways and changing natural conditions. Even in New Orleans where the city proper is below the level of the river, the new deep sewers have so changed the water level as to drain the tops of wooden piles there. During a recent trip to New Orleans I saw foundations for a million dollar building in which wooden piles were used, where the new sewers had so lowered the water level as to expose piles in this foundation for 5 ft. of their length. It is a well known fact that in many of the buildings of Chicago, New York, St. Louis and other cities, water has been drained from the tops of wood piles and they have begun to decay with very serious results.

Here, then, is one of our local conditions which, if present, would make wooden piling dear at any price and with permanency in view gives the preference to concrete piles practically without any other consideration. Although the first require-

ment showed that wooden piles were about one-fourth cheaper than concrete piles of the same bearing power, yet the advantage of permanency will offer this difference in cost of the low water line at which the wooden pile must be cut off is only 3 ft. below the basement. Add to this the fact the uncertainty of the maintaining of the water line at the required level and the balance of the scales is decidedly in favor of concrete.

We now come to the consideration of the third requirement —the time of construction. Without a question of doubt in a large majority of cases there is considerable saving of time in the use of concrete in place of wood piling. This saving in time comes from decreasing of the excavation and the avoiding of shoring and pumping. It takes practically the same time to assemble a concrete pile driving plant as it does a wooden pile outfit and even if the made-up reinforced concrete pile is used, the piles can be made at once and the concrete allowed to set while the necessary excavation and assembling of plant goes on, or the first few piles driven can be shipped out of stock. In using concrete there are generally about one-half the number of piles to be driven and usually much time is saved, although there is no system of concrete piles of which as many can be driven as of wood piles under similar conditions. The best record for concrete piles is forty-two piles driven in one ten-hour day. When it comes to the capping and footing the considerable reduction in the size by the use of the concrete pile makes a great saving in time possible. This saving in the time of construction means a gain in rent on the finished building, but is, however, often overlooked by prospective builders. It is declared that in the construction of the building of the Pittsburgh Terminal Warehouse and Transfer Company, the rent for the time saved by the use of concrete piles over the next available form of foundation, actually paid for the foundation itself. While this was not in comparison with the wooden pile foundation, which in this case was out of the question, it shows the importance of this point.

In conclusion, we may sum up the comparison as follows:

The only disadvantage of concrete piling is in the slightly increased cost over wooden piles having the same bearing power.

This, however, is only for the naked, uncapped pile. The advantages of concrete over wood are, first, its permanency under any conditions, regardless of the nature of the soil; second, the saving in cost due to the great reduction in the size of the footings made possible by the use of fewer piles of greater bearing power; third, no danger as to the lower water line, thus saving considerable excavation and all shoring and pumping; and, finally, the gain in building rental and saving of interest charges on investment due to the speed made possible by the substitution of concrete piles for all other types. Now it is apparent that in the total cost of a foundation, concrete piles afford the greatest economy in construction.

VALUE AND COST OF STEEL CENTERS FOR THE CONSTRUCTION OF CULVERTS AND BRIDGES.

By L. H. Scott.*

The bridges of the world that have stood the greatest test of time are arches. Some of the stone arches built by the Romans over two thousand years ago are in good condition to-day. These arches were without reinforcement and if an arch properly built of stone will stand for ages, one of concrete and steel is the very best type that can possibly be built. Arches are by far the strongest type of bridge construction, as an arch can be so designed that the entire strain will be compressive instead of tensile. There is an impression that arches are not practical in level countries, which is not so in the opinion of the writer. We have been building arches in the level sections of Illinois with the very best of results.

Since concrete has met with such favor as a factor in permanent highway construction, especially in the use of arched culverts and bridges, and since the building of culverts and bridges necessitates considerable time and expense in the construction of forms, under the prevailing method of using lumber, and wishing to be of some service to our great industry. I take great pleasure in describing a method of forms for arches by means of a system of sectional forms made of steel which is, in my opinion, far in advance of the old methods as to cost, time, efficiency and symmetry.

The writer has been engaged in the construction of arched culverts and small bridges for the past three years. The first two years our Company used wood forms in the usual manner. We had just the same trouble all of you have had in this class of work, perhaps more than the average, perhaps less, but trouble, nevertheless. It is after a season of bridge building that has been both very satisfactory in every respect, especially from a financial

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point of view, and very pleasing to the county and township officials with whom we have dealt, that I describe the system of steel forms we use.

These forms are made of sheet steel connected with channel and T-irons by means of 5/16-in. button-head stove bolts. The sheets at retaining or end walls are connected by means of channel irons running the entire length of the wall, while the sheets over the arch are connected and supported by means of T-irons bent to the proper radii. The rigidity of the sheets themselves together with the channels at retaining walls and the Ts under the arch, eliminate the need of any bracing other than the bolts that are used to hold the channels together in retaining walls. The form set up in place is a veritable bridge in itself, with practically the same effective area of waterway as the finished bridge. All contractors in this line of work will certainly agree that this form in place is not only a great saving, by eliminating the use of bracing and underpinning, all of which are treacherous, but also from probable loss by freshets while the work is underway. As this form cannot be harmed by any freshet that will not harm the finished bridge, the contractor may feel relieved of any liability from that source. After the foundation is laid there is nothing to fear from rains.

This sectional form is set upon the foundation. For the ordinary culvert and small bridge—say a 15-ft. elliptical arch—but two men and two days are required. These two men are simply good honest workmen who know how to hold a wrench or turn a screwdriver. Think of a form like that being set up in so short a time by two ordinary workmen, the expense of which would not exceed $10.00. Compare this with the cost of forms for the same in wood.

The superstructure for this form consists of ribs of T-irons, making the span in two pieces that are coupled in the center by a plate similar to that used in coupling small rails. This joint is wedged apart by means of a cut nail, driven between the T ends, for the purpose of affording slack by drawing out when the form is to be taken down. As soon as two of these ribs have been coupled and placed, the first arch sheet is bolted on, after which the form is self-supporting. Other rib arches and arch sheets are

simply bolted on until the form is set up. This work goes on very rapidly as the man, on the outside, places the sheet and inserts the bolt, and the man on the inside turns the burrs on by means of a socket wrench in a carpenter's brace. The arch sheets used are 12 gauge steel, all punched carefully to a templet so that they will fit exactly with either side up or either end to. The workman simply brings a sheet of steel that requires no fitting instead of a piece of lumber that invariably does. The retaining wall is constructed of 10 gauge steel and channel irons stayed by means of ½-in. bolts connecting the channels at intervals of 3 ft. These bolts are pulled out of the wall when the form is taken down, leaving holes which are very essential as weep-holes. All arch sheets are exactly 8 ft. long and 2 ft. wide, and the sheets, for retaining walls, are 10 ft. long. All sheets are alike, except that the arch sheets which join the retaining walls are so shaped as to provide for the necessary batter in the retaining wall, and the retaining wall sheets which abut the arched portion are cut to correspond to the radius of the arch. These sheets belong to a particular size bridge form, also the iron ribs. All other sheets and parts may be used in any size bridge.

These sectional forms are prepared so as to construct arches of any span from 5 ft. up, in multiples of 5 ft. One of these forms may be used an indefinite number of times and is always as good as new, while it is impossible to use lumber more than three times with any satisfaction, no matter how good the quality, or how painstaking the form gang.

Steel forms of this type are lighter than a wooden form for the same size bridge. The form for a 15-ft. arch, complete with end walls, bolts, etc., weighs but 8,000 lbs. and can easily be hauled in two loads, but the material for forms for the same bridge in lumber weighs about twice that amount. It is a fact that there is less weight to transport in one of the forms than there is in the lumber, stakes, studding, and braces that are required for the forms in wood. You also have the satisfaction of knowing that you have just what is required for the work instead of having to send for more material or to haul more than is necessary. The point is simply this: every pound of these steel forms counts for service without any extras to haul.

One of the chief reasons that these sectional steel forms are money savers, money makers, and a good investment for the contractor engaged in such work, is that they will enable him to figure closer and still allow himself a better margin for profit than he possibly can when using lumber. Another reason is that these forms are perfectly tight and do not leak in the least, and the finished work not only looks much better, but is better. When wood forms leak through the cracks, you are losing your cement and you do not know how much. Another reason, which is by far the most important one, is that the arch built in one of these forms is perfectly true in all lines, symmetrical in every feature, and a thing of beauty that will stand in evidence, always showing what may be built on our public highways instead of those rough structures we so often see.

THE PRESENT AND FUTURE OF THE CEMENT BLOCK. ITS MANUFACTURE—ITS AVAILABILITY—ITS COST.

By J. Augustine Smith.*

Cement blocks are destined to play an important part in all forms of construction work in the future; concrete constuction is here to stay. It has every virtue possessed by any other building material, and additional ones. When we look back and see the development of the cement block; note the difficulties through which it has passed; consider the mistakes that have been made both in its manufacture and exploitation; it is a wonder it has survived, and it would not have survived, had it not inherently the virtues it possesses.

I need not call your attention to the dark period of the past; you are all familiar with the history of this material, how it was first molded in sand, then in wood forms, then in iron forms, then came the machine for manufacturing them, then a period of strong effort to have them used in construction work with indifferent success, then a period of constant pioneering, and finally the invention of a simpler machine for producing them that opened the way for a flood of entrants into the business. With the flood came many incompetents, and with the flood, also, there arose, like mushrooms in the night, a rush of machine manufacturers whose strongest desire was, in many cases, to sell machines regardless of future business. Designs were furnished which produced blocks of the rankest artificiality in rock designs, the blocks were in many cases untrue in measurements, deficient from a structural standpoint, and, because of the lack of business training or business instincts of many who entered the field, the blocks turned out were porous, imperfectly made, an eyesore and a detriment to the business.

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It is not necessary to dwell upon the dark side of the picture too long, however, for there is a bright side, an encouraging side, a side of splendid promise in the cement block industry. In every great business we find a first period of enthusiastic effort, then the lull which comes, and then the conservative, painstaking, upbuilding era which ensues, and which means the development of the business on fundamentally correct lines.

Since the unpromising beginning which I have just related, perhaps it is necessary to show the development of concrete blocks from that beginning. In the first place, many machines fell in the hands of incompetent people, people who had no experience whatever with concrete, knew nothing whatever of the selection of aggregates, mixing of the material, or curing of the block, and they, therefore, found the easiest way to turn out blocks was to make them dry tamped. They added too little water to secure proper density. The development of the manufacture of good concrete block in this regard has been marked and pleasing, until now, instead of dry tamped blocks, they are tamped wet, just as much water being added as will permit the block to be removed from the machine without sagging or sticking. I, therefore, desire to say that it is essentially necessary for the proper manufacture of good cement blocks to select your aggregates with great care. You should use that proportion of sand and gravel which will secure the least possible voids. Then, proper mixing is essential. If hand mixed, the mass should be turned over at least three times in a dry state and at least three times in a wet state, after the water has been added. You will find also if you use an ordinary rake as a last means for mixing your concrete, both in a dry and in a wet state, this will help the mixing of the materials very much. I need not say that this should be done after the mass has been turned at least twice with a shovel.

I want to lay particular stress upon the use of the proper kind of water and the necessity for measuring the amount of water used in making cement blocks. It is my experience in several cases where blocks of different colors and shades were produced, using identically the same material, the same cement, and the same water, it was found that this change of color was

caused by the water used. Tanks were erected for settling purposes, and then the cleared water used in the manufacture of the blocks, with the result that this discoloration or change of color disappeared entirely.

With regard to the use of the proper amount of water, the question as to which is the better, the wet or the dry mixing of concrete, has been much discussed, and recently in Germany there were given out the results of extended experiments covering some four years. From these reports the conclusion is drawn that the smallest amount of water which produces a mixing suitable for ramming gives the strongest concrete. The results of these experiments confirm that which other experiments covering shorter periods of time indicated, and will not occasion any surprise. At the same time, the concrete worker who attempts to use the smallest amount of water which will produce a mixture suitable for ramming will find many practical difficulties. There is, therefore, but one thing to do, viz., measure the water as well as the other aggregates for each batch mixed.

The proper curing of blocks after they are made is, of course, essential; indeed, it is very essential, but it only plays its part in the whole process of manufacture. The possibilities of the cement block business have been too greatly underestimated until the last few years, and even now there are large fields still open. A few years ago concrete blocks were used for little less than foundations and cellars. The blocks of those days were usually of rock design, and, as we have pointed out, the very worst rock effect at that. It seems strange upon consideration of this part of the business that such a design was chosen for the most general exploitation of cement blocks which represented in the highest degree the artificial character of the product, and at the same time was the most difficult to closely imitate. There is no dressed stone design that varies so greatly as the rock, or quarry, faced stone, and there is no dressed natural stone so cheap as this design; therefore, in selecting this one for exploitation of cement blocks, the extraordinary and peculiar fact was brought home to us all that it required a greater variety of face plates and required also greater care in manufacture and use of this design to produce a pleasing effect than with any other that could be secured.

"Every cloud has its silver lining," however, and I believe the present is showing, and the future will still more show, the extraordinary development of this material. Go where you like, east, west, north or south, everywhere, you will find evidences that concrete blocks have come to stay. You will find foundations, walls of houses, schools, churches, public buildings, factories, and manufacturing plants constructed with cement blocks. Good concrete blocks are now being sold at a figure where they compete with common brick, and where pressed brick or cut stone was formerly used concrete blocks have now an ever-enlarging field. This is but as it should be, for there is no virtue in any other building material not possessed by cement blocks, to which may be added the fact that they can be produced in as high a grade as any other material from an architectural and structural point of view, at a cost lower than any other building material except lumber. Lumber is becoming scarcer and more expensive, and as a consequence people everywhere are looking for another building material, and right here the concrete block steps in and claims its own. The plastic material of which it is composed makes it possible to produce it in any desirable design. Its remarkable resistance to fire has been thoroughly attested, and in a few more years we will see concrete blocks used as commonly as brick is now, and that means that blocks will be used in the construction of the great majority of buildings.

Of all forms in which concrete can be used, the cement block represents the most approved method. Why? Because it eliminates to the largest extent possible the human equation in making concrete; because a cement block is a unit that can be inspected before it goes in the building, and, therefore, its stability and perfection can be assured; because it represents the use of a ventilated wall, and this fact is a distinct advantage in construction. Furthermore, this ventilation saves material and permits the installation of wires and pipes within the walls of the building itself, and further, the block when delivered on the job is finished in design and needs no further dressing of the exterior surfaces.

Designs are now produced for cement blocks which make it possible to meet every demand of the architect for beauty of

design. One of the most promising developments in the use of cement blocks has been shown lately in their use in conjunction with reinforced concrete columns, beams and girders. Many buildings have lately been constructed of reinforced interior, with concrete blocks for the exterior walls and partitions.

MATERIALS.

The materials most commonly used in concrete block manufacture are sand, gravel, or crushed stone, and Portland cement. A lengthy paper could be written on sands alone, so that I will touch upon this subject but very briefly. The term sand is confused by a great majority of block manufacturers. In concrete work sand is termed as that material which will pass a quarter-inch screen, and a good sand should be graded from coarse to fine, with the coarser grains predominating over the finer ones. A sand which is well graded from coarse to fine is the one which will make the strongest concrete, and such sand makes the densest concrete. The strength of concrete varies directly with its density. This is a well-known fact and one about which much has been written.

Let me lay down this fact, however, and call your particular attention to it, *that no concrete can be stronger than the materials from which it is made.* Many block manufacturers insist on using for facings a very fine sand in mixtures of 1 to 2, not realizing that a coarse, well graded sand will give them as strong a facing with a 1 to 3 mixture and a block of as good appearance as well. They make the excuse that they must use a fine sand in order to get a smooth block. When the tamping is directly against the face, as in most machines, the finer particles work themselves through the coarser one into the face, and thus the surface is just as smooth as though a fine sand were used. Therefore, just as good a surface can be obtained by using coarse, well graded sand, and such a surface will be far stronger and more waterproof. The reason for this is that in a fine sand the grains are nearly all uniform in size, and the percentage of voids will be between 40 and 50 per cent., whereas, in a well graded sand they may be as low as 25 per cent., consequently, when using the same amount of cement with both sands, the coarser sand will

make a denser, stronger and more waterproof concrete. Another reason is that, for a given volume, the fine sand will have a greater number of particles, and consequently there is more surface to be coated with the cement mortar than in the case of the coarser sand. This means that more cement is required.

It is very important to mix the aggregates with a mixing machine of a good type. The machine by its operation must perform its work correctly, and coat the aggregates properly, in the process of mixing.

THE FACING OF CONCRETE BLOCK.

The subject of facing cement blocks is one which well deserves attention. Blocks are usually sold because of their good appearance and satisfactory qualities, and the man who faces his blocks with material which gives them life, is the one who gets the business.

One of the serious objections to concrete blocks in the past is their dark gray appearance. This can be overcome by using light colored sand, or crushed stone, and a white Portland cement, which will give a light gray effect. If a pure white effect is desired, then white cement should be used, with white sand, or crushed stone, mixed with a little marble dust. It is very difficult to obtain a coarse white sand, although I have seen a few samples which were quite coarse. A fine white sand used alone with cement will not make a thoroughly waterproof facing. In order to make such facing waterproof I have found it necessary to use a proportion of marble dust, or crushed stone, with the sand.

Care must be taken not to use too much marble dust, for if too much of this is used, the facing will check and show unsightly cracks. For this reason, marble dust should never be used alone with cement. Usually, the checks and hair cracks referred to, will not show until the blocks have aged several weeks, and even months, but eventually they are bound to come. The amount of marble dust to be used, should not be more than 1½ parts of marble dust to 4 parts of white sand. If the facing is too rich in cement, checks and hair cracks are liable to appear as when marble dust is alone used with cement. Very good results can be obtained by using limestone screenings, from

coarse to fine, which will pass a quarter-inch screen, but, usually, it is advantageous to use a little white sand with this as well, in order to produce a smooth, dense surface.

PROPORTIONS OF AGGREGATES.

This brings us up to the proportions which should be used to produce maximum strength in cement blocks. The specifications of this Association require a minimum crushing strength of 1,000 lbs. per square inch of superficial area at the age of 28 days. They further call for proportions of 1 part cement, 3 sand, 4 gravel. Where a good coarse sand is obtainable it is sometimes more economical to use sand only in the proportion of 1 part cement to 4 parts of sand, pit run. If the sand is coarse, and well graded, such blocks will develop over 1,000 lbs. per square inch in 28 days.

I call attention to this part of the specifications of the Association because it has been found in actual practice that it is frequently not possible to get good gravel, while good sharp sand can be found in quantities. I therefore call your attention to the comparative cost of blocks when using proportions of 1 part of cement to 4 parts of sand, pit run, when same is a good coarse grade, as against 1 part of cement, 3 parts of sand and 4 parts of gravel, when sand and gravel have to be screened. The cost is then considerably higher than the ordinary sand. As, for instance, 100 blocks 8 x 8 x 16 ins. will require:

When made 1 part cement and 4 parts sand:

1.41 yds. of sand at 60 cents	$ .85	
2.63 bbls. of cement at $1.50	3.95	
		$4.80

When made 1-3-4, and with a facing 1-2:

1.05 yds. of gravel at $1.00	$1.05	
.79 yds of sand at $1.00	.79	
2.02 bbls. of cement at $1.50	3.03	
		$4.87

Therefore, you will see, in such cases as the above, where the price of cement, sand and gravel is considerably higher than that of pit run sand of a good coarse character, it is more economical

to use 1 part of cement to 4 parts of sand, as the materials in this will cost less, and the labor of mixing will also be less.

It has always seemed to me that it is most important to get the requisite strength regardless of proportions, and if a 1-4 sand concrete will give these results, I say, use a 1-4 mixture. The same holds true of a 1-3-6 mixture, providing it will give the required strength. Proportions of 1-2-4, 1-3-4, 1-2½-5, and 1-2-5, should all prove rich enough in cement to make blocks which will develop a crushing strength of 1,000 lbs. per square inch at 28 days. I, therefore, think our specifications ought to allow the use of any proportions that will meet the strength requirement.

CURING.

Wet tamped blocks should be sprinkled two or three times daily for a period of 2 to 3 weeks. They should be sprinkled after molding as soon as the concrete has obtained its initial set, which it will do in from 12 to 24 hours.

The temperature of a curing room should range from, say, 80 to 180 deg. F., provided the blocks are kept sufficiently wet. The temperature of the curing room should never be lower than the freezing point of water, for if carried below this point, the blocks will freeze, and even though they are not injured, the setting of the cement will be delayed; in fact the blocks will be no stronger at the time they thaw out than when they first froze, for the process of hardening stops at the time of freezing and does not resume until the blocks are thawed out. Many manufacturers will use blocks a few days after they are made, but this is a great mistake, and should never be allowed, as blocks cured by the sprinkling method for a few days are not strong enough to build in structures, and it is just work of this kind that discredits the use of this material. Every now and then one can see blocks that are so crumbly that the surface can be cut away, and this, almost invariably, is caused by insufficient water in the mixing, or insufficient curing. It sometimes is caused by not using enough cement, but the former reasons are more often the case.

Another point I wish to emphasize is the fact that no amount of subsequent sprinkling will make up for an inadequate amount of water in the mixing of the concrete, that is to say, if a man

uses but half as much water in his mixing as he ought for a good block, no amount of subsequent sprinkling will make that block what it should be.

WATERPROOFING.

This is one subject that has had the earnest attention of many people. Good, dense concrete, absolutely waterproof and impervious to moisture, can be made by the proper selection of aggregates, the proper mixing of the materials, the addition of a sufficient amount of water and a proper curing of the block. This is particularly true when there can be used a rich facing mixture, but to make assurance doubly sure, there has been devised, waterproofing compounds and fillers to make the blocks dense and impervious to moisture.

The Government is conducting a series of experiments at the Testing Laboratories at St. Louis, which will be reported to the Association shortly, and the results will clearly demonstrate the effectiveness of such methods.

COST OF BLOCKS.

I now come to the subject of cost of cement blocks, and have prepared data, showing the comparative costs of cement blocks and common brick laid in the wall. In drawing up this table of costs, however, I have used faced blocks entirely throughout my computation, and have compared faced blocks with common brick in the figures given.

I have also prepared a comparative statement of faced cement blocks and facing brick in conjunction with ordinary brick laid in the wall, as well as a comparative cost of cement blocks and monolithic construction. In getting up this data I have had an eye to the absolute conservatism that should surround such a table in figuring costs, and I think you will find that this subject treats in a conservative way. If I have erred at all, it has been in placing the cost of blocks too high, and the cost of brick too low, but I have done this with the idea of being ultra conservative so far as blocks are concerned. Furthermore, I have made a distinction in this cost data, as between the small-sized plant, operating with two or three men, mixing

by hand, and buying materials in small quantities; and, the thoroughly and perfectly equipped plant where the materials are elevated, pneumatic or power tamping used, materials bought in quantity, cars and tracks used for the transportation of the block, and a greater number of blocks turned out per day. A well thought out, complete plant, properly equipped, will, of course, reduce the cost of the stone turned out materially.

Proportions of 1-3-4.
Facing ½ in. thick of 1 part cement to 2 parts sand.

100—8x8x16 in. blocks require:

1.05 yds. gravel	at	$1.00	$1.05	
.79 yds. sand	"	1.00	.79	
2.02 bbls. cement	"	1.50	3.04	
Labor	"	.02¾ per blk	2.75	
				$7.63

100—8x10x16 in. blocks require:

1.4 yds. gravel	at	$1.00	$1.40	
1.06 yds. sand	"	1.00	1.06	
2.62 bbls. cement	"	1.50	3.94	
Labor	"	.03 per blk	3.00	
				$9.40

100—8x12x16 in. blocks require:

1.68 yds. gravel	at	$1.00	$1.68	
1.27 yds. sand	"	1.00	1.27	
3.08 bbls. cement	"	1.50	4.62	
Labor	"	.03¼ per blk	3.25	
				$10.82

100—8x8x24 in. blocks require:

1.62 yds. gravel	at	$1.00	$1.62	
1.23 yds. sand	"	1.00	1.23	
3.12 bbls. cement	"	1.50	4.68	
Labor	"	.04 per blk	4.00	
				$11.53

100—8x10x24 in. blocks require:

2.02 yds. gravel	at	$1.00	$2.02	
1.53 yds. sand	"	1.00	1.53	
3.80 bbls. cement	"	1.50	5.70	
Labor	"	.04¼ per blk	4.25	
				$13.50

100—8x12x24 in. blocks require:

2.43 yds gravel	at $1.00	$2.43	
1.82 yds. sand	" 1.00	1.82	
4.46 bbls. cement	" 1.50	6.70	
Labor	" .04½ per blk	4.50	
			$15.45

100—8x8x16 in. blocks will displace from 1,333 to 1,422 brick.

1333 brick laid in wall at $14.00 per M. cost		$18.67
100—8x8x16 in. faced blocks cost	$7.63	
These sell at 4 cts. profit per block, cost,	$11.63	
Laying in wall costs	3.00	
		14.63
Saving on every 100 blocks		$4.04

100—8x12x16 in. blocks will displace from 2,000 to 2,133 brick.

2000 brick laid in wall at $14.00 per M. costs		$28.00
100—8x12x16 in. faced blocks cost	$10.82	
Allowing 4 cents profit per block, cost	$14.82	
Laying costs	4.00	
		18.82
Saving on every 100 blocks		$9.18

100—8x8x24 in. blocks will displace from 2,000 to 2,133 brick.

2000 brick laid in wall at $14.00 per M.		$28.00
100—8x8x24 in. blocks cost,	$11.53	
Allowing 5 cents profit per block, cost,	$16.53	
Laying costs	5.00	
		21.53
Saving on every 100 blocks		$6.47

100—8x12x24 in. blocks will displace from 3,000 to 3,200 brick.

3000 brick laid in wall at $14.00 per M. cost		$42.00
100—8x12x24 in. blocks cost	$15.50	
Allowing 6 cents profit per block cost	$21.50	
Laying at 7 cents per block	7.00	
		28.50
Saving on every 100 blocks		$13.50

A high grade of facing brick, costing $21.00 per thousand, will cost, laid in the wall, $48.00 per thousand. We have assumed common brick at $14.00 per thousand.

An 8 in. brick wall faced with pressed brick as per the above, and equivalent to 100—8x8x16 in. blocks, will require:

667 Pressed brick at $48.00 per M	$32.00	
667 Common brick at $14.00 per M	9.33	
		$41.33
100—8x8x16 in. faced blocks laid in the wall costs		12.93
Saving on every 100 blocks		$28.40

A 12 in. brick wall, faced as above, and equivalent to 100—blocks 8x12x16 in. will require:

667 Pressed brick at $48.00 per M	$32.00	
1333 Common brick at $14.00 per M	18.66	
		$50.66
100—8x12x16 in. blocks laid in the wall costs		16.55
Saving on every 100 blocks		$34.11

The above figures allow 4 cents profit per block to the manufacturer. In a case like this the manufacturer would figure on a higher profit, as he is always sure of getting the job when competing with pressed brick.

An 8 in. brick wall, faced with pressed brick and equivalent to 100—8x8x24 in. blocks, will require:

1000 Pressed brick at $48.00 per M	$48.00	
1000 Common brick at $14.00 per M	14.00	
		$62.00
100—8x8x24 in. blocks laid in the wall cost		19.00
Saving on every 100 blocks		$43.00

These figures allow the manufacturer 5 cents profit per block.

A 12 in. brick wall, faced with pressed brick, and equivalent to 100—8x12x24 in. blocks, will require:

1000 Pressed brick at $48.00 per M	$48.00	
2000 Common brick at $14.00 per M	28.00	
		$76.00
100—8x12x24 in. blocks laid in the wall cost		27.65
Saving on every 100 blocks		$48.35

The above figures allow 7 cents per block profit to the manufacturer.

As stated above, when competing with pressed brick and cut stone, the manufacturer will usually charge a higher price for his blocks, as he will have a greater leeway.

The above computation on brick is figured upon the least displacement of 100 blocks in the wall: 1333 brick is figured on a basis of 22½ brick to the square foot of 12 in. wall, three brick thick, or, 15 brick per square foot of 8 in. wall. The same is true in every other computation, as I have taken the least displacement possible on which to base my figures so that the results cannot be questioned from a standpoint of favoritism to cement blocks. Furthermore, all the above is based on costs shown in small-sized plants, operating with two to three men, mixing by hand, and buying materials in small quantities.

The labor costs include all fractional and window jamb blocks. Furthermore, the costs shown are on faced cement blocks against common blocks. Where pneumatic, or power tamping, is used, materials are bought in quantity and a greater number of blocks turned out, the cost can be cut down considerably, and will more nearly approach the following:

100—8x8x16 in. blocks will require:

1.05 yds. gravel	at	$ .80	$ .84	
.79 yds. sand	"	.80	.63	
2.02 bbls. cement	"	1.30	2.63	
Labor,			1.83	
				$5.93

This assumes a reduction in labor of 33 1/3 per cent. Figuring on the above basis the other sizes will cost as follows:

100—8x10x16 in. faced blocks will cost	$ 7.46
100—8x12x16 in. " " " "	8.55
100—8x8x24 in. " " " "	9.00
100—8x10x24 in. " " " "	10.63
100—8x12x24 in. " " " "	12.21

100—8x8x16 in. blocks, with 4 cts. profit per block, can sell at	$9.93	
Laying in wall will cost	3.00	
		$12.93
Equivalent brick (1333) laid in wall at $14.00 per M.		18.60
Saving on every 100 blocks		$5.67

100—8x12x16 in. blocks, with 4 cts. profit cost	$12.55	
Laying costs	4.00	
		$16.55
Equivalent brick (2000) laid in wall at $14.00 per M.		28.00
Saving on every 100 blocks		$11.45

100—8x8x24 in. blocks, with 5 cts. profit per block cost	$14.00	
Laying costs	5.00	
		$19.00
Equivalent brick (2000) laid in wall at $14.00 per M.		28.00
Saving on every 100 blocks		$9.00

100—8x12x24 in. blocks, with 7 cts. profit per block costs	$20.65	
Laying costs	7.00	
		$27.65
Equivalent brick (3000) laid in wall at $14.00 per M.		42.00
Saving on every 100 blocks		$14.35

An 8 in. monolithic wall, 1-3-5, figured on a basis of $1.00 per cu. yd. for gravel and sand, and $1.50 per barrel of cement, will cost about $7.12 per cu. yd. under very fair conditions.

100—8x8x16 in. faced blocks cost	$5.93	
Laying costs	3.00	
		$8.93
Cost per cu. yd.		4.09
Saving per cu. yd. in favor of blocks		2.93

A 10 in. monolithic wall will cost $6.52 per cu. yd.

100—8x10x16 in. faced blocks cost	$7.46	
Laying costs	3.50	
		$10.96
Cost per cu. yd.		3.99
Saving per cu. yd. in favor of blocks		2.53

A monolithic 12 in. wall will cost $5.02 per cu. yd.

100—8x12x16 in. faced blocks cost	$8.55	
Laying costs	4.00	
		$12.55
Cost per cu. yd. of wall		3.82
Saving per cu. yd. in favor of blocks		1.20

100—8x8x24 in. faced blocks cost	$9.00	
Laying costs	5.00	
		$14.00
Cost per cu. yd. of wall		4.27
Saving per cu. yd. in favor of blocks		2.85

100—8x10x24 in. faced blocks cost	$10.63	
Laying costs	6.00	
		$16.63
Cost per cu. yd. of wall		4.05
Saving per cu. yd. in favor of blocks		2.47

100—8x12x24 in. faced blocks cost	$12.21	
Laying costs	7.00	
		$19.21
Cost per cu. yd. of wall		3.89
Saving per cu. yd. in favor of blocks		1.13

I desire to call your attention to the fact that the above figures are based, in the one case, on cement blocks in a finished wall, while in the case of the monolithic wall, the superficial surfaces still have to be taken care of, which adds to the cost, and which is not included in the above figures. These figures, therefore, show how much cheaper concrete block walls are than the solid monolithic walls, and the above figures are on the plainest kind of monolithic work, and do not take into account any reinforcing.

COST OF WHITE FACING FOR CEMENT BLOCKS.

The cost of white cement for white facing, is nearly 2¼ cts. per block, 8x8x16 in., and should be figured at 3 3/8 cts. per block, 8x8x24 in., on the basis of $5.00 per barrel for white cement.

White sand will cost about 1 ct. for the 16 in. blocks and 1½ cts. for the 24 in. blocks. This is figured on a facing of 1 cement to 2 sand, facing to be ½ in. thick.

The submission of the figures I have quoted above, and the showing in reduced costs of the complete, thoroughly equipped plant, brings up the question of the proper equipment, of a complete and up-to-date plant, and the profit to be made by conducting such an establishment. My experience has proven that this business, properly conducted, with a plant properly equipped, is a very profitable one indeed. As a matter of fact, I know of no business to-day in which a man can engage with such assurance of success, and with so small an investment to begin with, as in the cement block business.

I desire to call your attention, however, to the fact that it is just as necessary to exercise good judgment and common sense in the conduct of this business, as it is in any other. As a matter of fact, the great lack of ordinary business judgment, and ordinary business method, has been one of the great causes in the past for many of the failures which have taken place.

A good, complete plant should be well laid out, with sufficient buildings, and sufficient yard room in which to conduct the business satisfactorily and enconomically. Elevators should be used to elevate the materials above the mixing machine; mixers are essentially necessary; power tampers should be installed, and I believe, the future will demonstrate that cement blocks should be cured by high pressure steam. I believe the tests which were carried on at St. Louis,* and which have been conducted for some time past, have conclusively proven that there is a method of steam curing, under pressure, that is safe and sound, and that this method produces results that are really astonishing.

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*Structural Materials Testing Laboratories, U. S. Geological Survey.

In conclusion, let me say, that the future for cement blocks is most promising. Indeed, the use to which this material will be put will be of the widest character, and it is difficult to exaggerate the importance of cement blocks in future construction work. Their manufacture is a business in which great profit can be made; it is a business which is worthy of the highest craft and care, and if you will perform your share in turning out blocks of acceptable design to the architect, blocks of good appearance, well cured, and which will be impervious to moisture, you will one day reap the harvest you have worthily prepared.

VALUE AND COST OF STEAM CURING OF CEMENT HOLLOW BLOCKS.

F. S. PHIPPS.*

A great advance in the use and reliability of concrete building blocks has been made possible through the steam curing of such blocks. The object of this paper is to give an insight to the methods and system used by the Central Stone Company. It is to be understood, however, that nothing said is to be inferred as advancing any claims as to the superiority of the product.

I. ADVANTAGES OF STEAM-CURED BLOCKS.

A block cured with steam vapor is harder and stronger at the expiration of 24 to 30 hours than a block cured by the old way of sprinkling or spraying at the end of 7 to 10 days. The method of manufacture is as follows: The blocks are made in ordinary machines and transferred into the ovens where there is no sun or current of air to cause them to dry before they start to set. As soon as an oven is filled it is closed and within one to two hours the steam is turned on and it immediately condenses upon the block the same as dew on grass, and in less time than it is possible to spray a block, it is filled with moisture. In this way a block can be given so much moisture that it will become mushy and mash before the cement sets. This fully refutes the argument that steam curing dries the blocks before they have the proper amount of water.

If a block produced in 24 hours is equally as good or better than a block made in 7 days under the sprinkling system, is this point not worth considering in installing a steam-curing plant? Further, blocks can be delivered upon a contract within 48 hours after starting the plant, doing away with the one great objection the buyer has against concrete blocks—that of being compelled to

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wait several days for them after placing the order. A denser block can be produced as the steam does not wash any of the cement from the block, as is the case with the sprinkling system. Also the color of the blocks is more uniform, regardless of the cement used. I have made blocks using dark, as well as light cement, and find them to be almost the same color; the steam gives them a lighter color than it had been possible to obtain before. With steam curing blocks can be made all winter, which gives the same opportunity to build with blocks as with brick. Again,

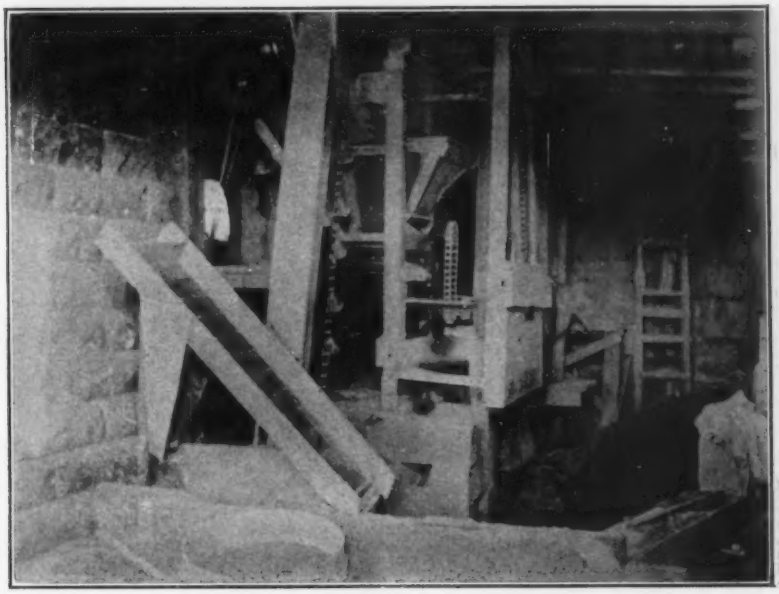

FIG. I.—INTERIOR OF SAND SHED.

in the case of rush orders, delivery can be made in 36 hours, or just as quick as stone can be obtained. It has been my experience that by steam curing, a better block is produced, both in color and strength, and a block that is much more salable than the old water-cured block.

II. COST OF MANUFACTURE OF CURED BLOCKS.

We are using Kaw River sand, which is sharp and clean and costs delivered, including shrinkage and waste, $1.10 per

yard. The price of cement at the present time is $1.25 per barrel. Our proportions range from 1-3 to 1-5 and our cost for 1-5 proportion is 3 cts. per ft. and for 1-3 is 5 cts. per ft. With one man to take care of the boiler, ovens, engine and the mixing of the materials, at $2.00 per day and two men to run the machines at $1.75 per day, we turn out 560 ft. of rock. Allowing 50 cts. for coal per day and $1.00 for office help, our blocks cost us for labor, very close to 1¼ cts. per ft. with the 3 cts. added for material in the 1-5 blocks, the cost will be 4¼ cts. per ft. and of the 1-3

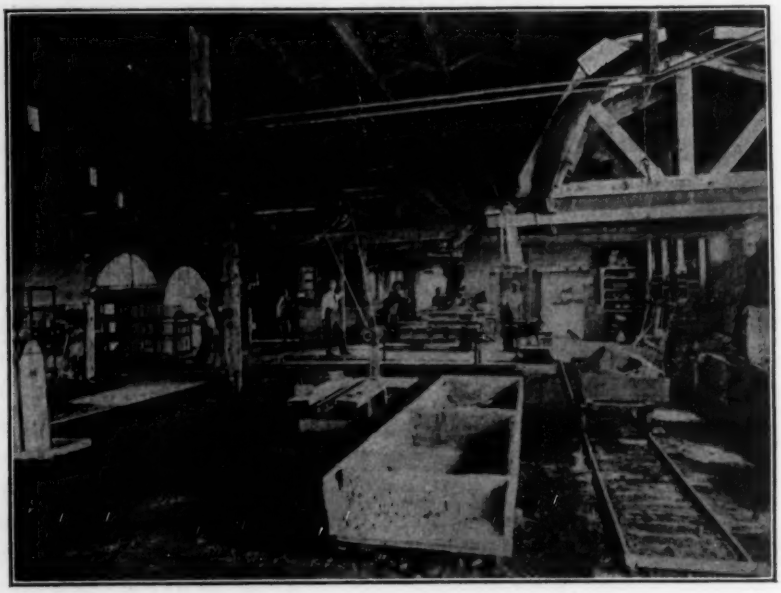

FIG. 2.—REAR PORTION OF PLANT, SHOWING LOCATION OF OVENS AND MACHINERY.

block, 6¼ cts. per ft. These figures do not allow for insurance, wear and tear on machinery or the manager's salary. If three men were used on the machines, instead of two, the cost would be no greater for mixing or curing than it is for two men. As near as we have been able to ascertain, 1,000 to 2, 000 lbs. of coal will cure three ovens of blocks, each oven containing from 140 to 160 blocks. Our men on machines are able to turn out 140 blocks,

32 ins. long by 9 ins. high, giving 2 sq. ft. to the block. The blocks we make for building purposes are 4-in. and L-shaped, ranging from 4 to 32 ins. To build a wall from 8 to 12 ins. thick, we use two 4-in. blocks, so the same must be figured on a 1-3 proportion for outside wall, at a cost of 6¼ cts. per ft. and 1-5 proportion for inside wall, at a cost of 4¼ cts. per ft., making a total cost of a 12-in. wall, 10½ cts. per ft. The hollow block we make is somewhat cheaper, as it is only 9 ins. high and 8 ins.

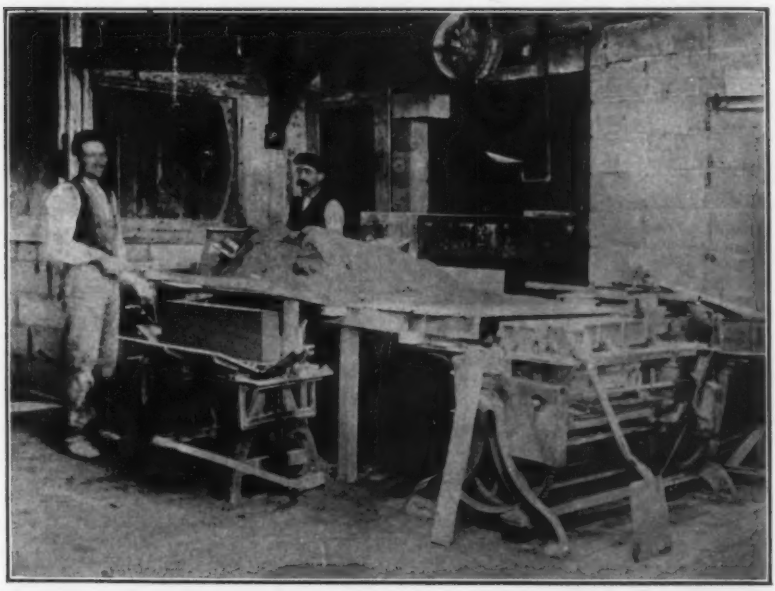

FIG. 3.—BLOCK MACHINES. MATERIAL IS DELIVERED FROM MIXERS TO TABLE IN FRONT OF OPERATORS.

wide. We make all sizes, but this is the most used. It costs about one-third less for material and about the same for labor.

III. PLANT.

The cost of a plant will depend on the size and equipment desired. We have a 25 horse-power boiler, which cost, with all piping and fitting, $225.00, and makes steam for 6 to 9 ovens. The ovens cost about $50.00 each. Almost any old boiler will answer, and the oven can be made of sheet iron (although I would not recommend this class of oven).

Our plant is 75 by 170 ft., with an office of 16 by 24 ft., divided into two rooms. At the rear of the plant, we have an addition of 20 by 85 ft. with a track running the full length of our yards and by means of switches and spurs we unload our material through the roof of our sheds and convey our blocks to the sheds for storage. We carry in front of our factory, that is seen by people passing on the street cars, a display of our special work.

Fig. 1 shows interior of the sand shed containing conveying and mixing machinery.

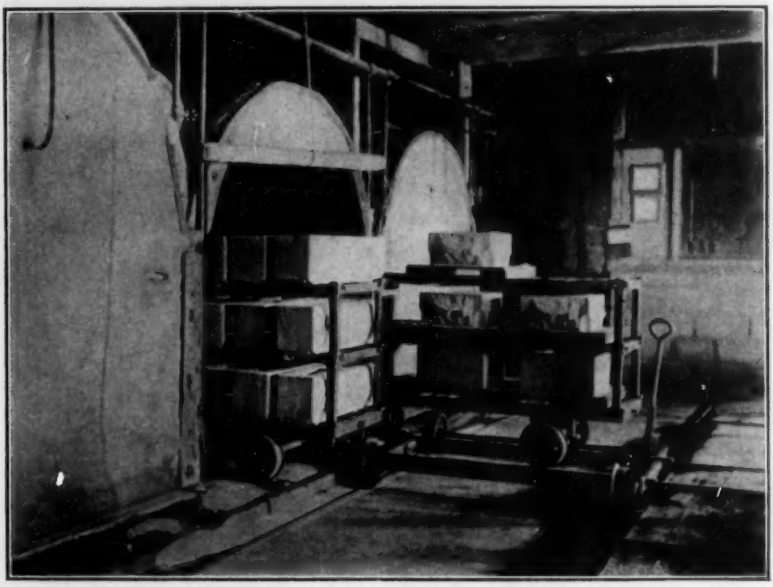

FIG. 4.—STEAM-CURED BLOCKS COMING OUT OF OVENS.

Fig. 2 is an interior view of the rear portion of the plant, giving you some idea of the arrangement of the ovens and machinery.

Material on table delivered from mixer, ready to be tamped in machines, is shown in Fig. 3. We manufacture all our sills, steps and special work in the front portion of our building.

Fig. 4 shows a lot of blocks coming out of the ovens, where they have been steam cured.

PROGRESS IN THE USE OF METAL FORMS WITH COMPARATIVE COSTS.

By W. L. Caldwell.*

Owing to the falling off in building operations during the past year, there has not been as much interest shown in the development of the metal forms as otherwise would have been, consequently there has not been the opportunity to develop this method to the extent anticipated. However, we have given the subject considerable thought and believe have materially improved on the suggestions submitted a year ago at the Convention in Buffalo.† At that time our company was handicapped in producing centering as effective as they desired, for the reason that they could not roll sheets below 16 gauge in 10-foot lengths, but at the present time are completing an extension to the rolling-mill when sheets down to 8 gauge can be rolled, which will give a range of gauges that will make it possible to produce a class of centering strong enough and efficient for any conditions which may be encountered in the construction of all classes of buildings.

It is essential that certain reinforcing members be heavy enough to, in turn, support and reinforce lighter members, so that the best results will be obtained. We, however, still hold to our statement of a year ago that, "It is better to have the centering material sufficiently flexible so that it can be easily straightened out after it has become deformed or dented and that will permit of the steel being sprung away from the concrete."

We have especially changed our ideas regarding the centering of columns so as to obtain a more universal system or application, in other words, so that the metal used can be adapted and adjusted to a greater number of variations. To this end we have adopted the use of corner angles for column centering, the width of the legs of the angles being one-fourth of

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† See Proceedings, Volume IV, pp. 286–302.

the width of the column. Using angles of this dimension leaves an open space between the legs of the angles down the side of the column equal to one-half the width of the column through which the girder and connecting beam may be connected with the column. The angles are held in position by cross-cleats. The rectangular space formed by the four angles is lined with either sixteen or twelve gauge sheet metal, black or galvanized as may be desired; the length of sheets may be 3 or 4 feet if desired allowing the concrete to be filled in more easily, at the same time forming a smooth, even mold for the concrete. These sheets will be forced out to place against the inner surface of the legs of the four angles by the weight of the concrete; the stiffness of this material being amply sufficient to span the one-half width of the column between the angles without bulging.

If the four corners of the column are desired rounded or chamfered, it is an easy matter to throw in a quarter round or flat strip of metal as a fillet in each corner inside of the lining of the rectangle, which will produce the desired rounded or chamfered corners.

The corner angles are so designed that they can be run continuously from story to story, not having to stop at an exact point for story height, neither is it necessary for all of the corner angles to be of the same length. This is a very important factor as it does away with considerable cutting and fitting and waste of material, thereby reducing the cost of the centering very materially.

Provision has been made at the point where the floor slab unites with the girder and lateral beam at the column for inserting a thin temporary metal form to prevent the concrete from coming up to, or interfering with the angle, leaving an opening through which the angle can be drawn up to the story above or down and out to the floor below as may be expedient. After the angles and column casing or centering have been removed, the hole left through the floor slab should be filled in with concrete to bring the floor slab in contact, at this point, with the column proper.

We have made compression tests on soft concrete in different size square columns up to 6,500 pounds pressure per square

foot. The heaviest gauge metal used in these tests was number sixteen. While the bulging increased with the size of the column, still, in no instance, was the set of the metal permanent, in each case it went back to its normal position after the concrete had been removed. These tests were made on plain sheet centering made in halves and not reinforced with angles. Since introducing the corner angles made of ten gauge metal this tendency to bulge has been eliminated, at least to a degree where no bad results are obtained. One set of column centering will allow for 4-inch variation in increased size of column without extra cost or additional material.

The girder boxes for molding the girders, which in turn carry the lateral beams, are formed after similar design as shown in our last year's model, excepting that we should use slightly heavier material, say 16 or 14 gauge, as conditions may require.

We believe that it is not feasible, in the construction of reinforced concrete buildings, to attempt to make the surfaces of the columns, beams, girders and intermediate floor area sufficiently smooth to compete with the plastered surface. We believe the best results are to be obtained by not attempting to have the surfaces sufficiently smooth for a finish but only uniformly true, and if the building demands a surface equal to plaster, the cheaper and better method is to float on a thin coat after the centering has been removed, covering up all marks, off-sets and unevenness caused by the centering.

It is almost impossible to devise a system of centering of sheet metal which can be put up and taken down readily and at the same time be economical, and not show off-sets or marks in the molded concrete equal to the thickness of the metal used, ordinarily one-sixteenth or one-twelfth of an inch. The balance of the surface would naturally be smooth and even and if the building were to be used for warehouse or factory purposes, it might be that marks of this character would not be objectionable if pointed up somewhat, thereby quite a saving could be effected in the cost throughout.

We do *not* rely on the girder boxes and lateral beam boxes being strong enough or stiff enough to support the soft concrete,

but they are arranged in such a manner that the adjustable splice for giving variation to the spacing of columns, can be supported with adjustable metal posts which need not be distributed when the balance of the centering is removed. These posts can be adjusted to any story height and used over and over indefinitely. We have made compression tests on these posts so that we know exactly what they will carry without failure.

Owing to the fact that the author is connected with the Berger Manufacturing Company, who do all classes of sheet metal work, it may be generally supposed they have a system of their own which they are endeavoring to put upon the market, but this is not the case. We have no such system, but are making a study of the subject so that we will be in position to co-operate with the different architects and contractors who wish to adopt metal centering in place of wood and in this way build up a trade for this product just as the lumbermen have to-day. We wish that all architects and contractors who have given this subject some thought and consideration, would co-operate with us in trying to devise some better and more effective method than has been used up to the present time. We stand ready, at all times, to give them the benefit of our experience and knowledge on this subject from a manufacturer's standpoint, and if any contractors wish to submit designs of their own for metal centering of this character, we will be pleased to furnish them with estimates of costs, providing their designs call for sheet steel instead of rolled members.

No doubt a great many of you will be interested in knowing just what this class of metal centering will cost and to get at it in the simplest way, let us take it per *lineal foot* of column, girder, and lateral beam and *square foot* of floor area. We have gone into this matter quite extensively, from time to time, and believe that the average results are about as follows:

Consider a 16-in. square column for a basis of calculation with a girder beam 8 ins. wide and 18 ins. deep below floor slab, with the lateral beams 6 ins. wide and 12 ins. deep, and floor slab 4 ins. thick.

For a structure of this character, we would recommend the use of 10-gauge material for the angles at the four corners of

the columns, 14-gauge for the lining of the columns, 14-gauge for the girder boxes, 16 gauge for the lateral beam boxes and 18-gauge material for the channel boards forming the inter-column area for carrying the floor slab, with all necessary reinforcing angles, bolts, etc., to set up the work complete ready for receiving the concrete.

Column centering, per lineal foot	$1.75
Girder centering, per lineal foot	1.00
Lateral beam centering, per lineal foot	.50
Floor area, per square foot	.13½
Adjustable girder and beam box posts, per linear foot	.05

Throwing the cost of all of these items against the floor areas, the average is about 45 cts. per sq. ft. This price is arrived at by taking a building 50x100 ft., with 28 columns and 18 bays or intermediate column spaces, each space or bay containing 237 sq. ft., in round numbers, each bay divided by 2 intermediate cross beams, or 3 spans to each bay. These figures will vary somewhat with the different types of buildings but will give you a fair idea of the average cost.

Under ordinary conditions, 4 men should set up or put to place 1,000 sq. ft. of this type of centering in 8 hours including 6 columns, 5 girder boxes, 14 lateral beams and 4 bays of floor channel boards. In other words, they will center one whole floor of a building 50x100 ft. in five or six days, at a cost of approximately 1¾ cts. per sq. ft. for labor.

There has been more or less discussion about the best means for keeping the forms from rusting and concrete adhering to them. As far as the rusting is concerned, this can easily be prevented by merely giving the forms a coat of linseed oil and repeat the dose at intervals, and the most effective way to keep the concrete from sticking is by the use of a coat of thin soap-paste put on with a large brush before using, this will prevent the concrete from adhering and at the same time does not injure the concrete. However, the forms should always be brushed clean and oiled after being struck.

It is my opinion that most of the talk against the adoption of metal forms is caused by prejudice and from ignorance of the many good qualities steel possesses as a centering material. If

a contractor were to encounter one-half the obstacles in the use of metal centering as in wood, I would not ask him to consider its adoption for a minute, but the trouble is that contractors who do this class of work are not accustomed to working in iron but are accustomed to working lumber, therefore, are prejudiced in its favor even though it does not give as good results. If architects and contractors will stand for just one-half as much bother, loss of time, money and patience, in trying to utilize steel for centers as they have and are expending to-day on lumber, they would soon see startling results. Most of you think it will take much longer to cut and fit steel centering as against wood, this is not the case, if you will employ sheet metal workers to oversee the placing of your forms and not try to do it with carpenters or masons who know nothing whatever about this class of work, the results would be entirely different. We have men who will erect a house complete of metal lumber just as quickly as carpenters will erect it of wood and the metal will be cut to fit on the job from stock lengths at that.

With the same number of men, a building can be centered with steel forms in one-half the time it takes to do it with lumber, and the job will be more satisfactory and the forms will be in good shape when struck, and can be used over and over, thereby paying for themselves time and time again as compared with wood.

Think of the great number of bad qualities and defects lumber is heir to. We will enumerate a few of them. It is expensive compared with its life, great waste in cutting to fit and refitting; it must be nailed more or less, which ruins it for future use; it absorbs moisture and warps which prevents its further use; it cracks, checks, and rots, swells and shrinks; it is not uniform in strength on account of knots, dry rot and shakes; it stains concrete more of less and leaves the marks of the grain on the surface of the concrete. It is heavy to handle, especially after becoming wet, and after once used can not be recut and adjusted without great trouble and expense; it has no value as scrap but an expense and makes two or three times as much bulk in a building as metal centering; it has not the strength per weight and cannot be handled one-half as readily;

it is combustible and increases the risk on the structure; is *unsatisfactory, unreliable,* and *insufficient.*

For an excuse many say: "Well, lumber is the best material we have found," when all of the time they are not hunting in any other direction. If you are tired of the game you find in the wood, do not hunt in the wood any longer but seek the plain or the river, you may come upon pleasant surprises and be well repaid for your adventure. Turn from that which is not satisfactory, fling away your prejudice and try something else, and for a starter *let it be sheet steel.*

Now what are some of the good points steel possesses over lumber? First, it is not as expensive, taking its life into consideration, can be had in desired lengths and sizes ready for use; it is fastened by bolts which can be removed without injury to the centering and is ready for future use; it does not absorb moisture and therefore does not warp, does not crack, check or rot, neither does it swell nor shrink; it is uniform in strength and reliability, does not stain concrete, is light to handle and can be readjusted to meet varying conditions without waste of time and material. It is not combustible and thereby reduces the fire risk to a minimum, and when scrapped has one-fourth its original value. It is *reliable, sufficient,* and *satisfactory.*

To tell you the truth and give you a friendly tip, the lumber dealer is in a transitory stage to-day, and in the near future you will know him no more, forever, he will be selling steel products, cements, etc., as many of them are beginning to do to-day. You will be driven to use steel, why not commence now?

In this connection it might be apropos for me to say that at the present time there is being produced what is called *metal lumber,* which is made from sheet steel. The steel is formed up into different building members which are commonly used to-day in the construction of all classes of light structures, such as joists, studs, rafters, roofing, siding, floor material, lath, door and window frames, sash, and, in fact, we build a house complete without the use of wood except when desired. These structures are encased in cement stucco and plastered on the inside with hard plaster. When completed they are absolutely non-combustible and sound-proof and at a cost very little above the cost of a wooden structure.

At the present time it is not desired to build structures complete but to furnish the steel joists, studs, rafters, lath, etc., for the interior of cement block or brick houses. In this way we can work hand in hand with the cement and concrete people in producing buildings that are absolutely non-combustible and sanitary, warm in winter and cool in summer, and in this manner produce a fireproof building at slightly advanced cost over wood interiors.

This all goes to show that concrete and steel are soon to become the future building materials, especially for buildings which are constructed of wood to-day.

DISCUSSION

Mr. Perrot.

MR. EMILE G. PERROT.—I have been making some experiments in Philadelphia. I built a garage with metal centers, and found that the difficulty at present is getting something which will be sufficiently adjustable to meet all conditions. My opinion is that the proper line to work along would be towards the adoption of some universal method of construction so that a few simple units of metal forms would enable one to meet every problem. I think these things will be worked out, and the metal center has an undoubted future. It will not be long until we are forced to use it. I think it is only ignorance that prevents our using it, as we have already demonstrated its practicability.

Mr. Gloyd.

MR. JAMES R. GLOYD.—I have made a few forms in a small way, using metal centers. I tried to eliminate lapping, using a light gauge of plate, but found it almost impossible to avoid it, owing to the fact that as soon as I tried to countersink the rivets or bolt heads, they pulled right through and did not hold. The only way I know to overcome this is to turn the edges of your plates, and this will give you a fin or joint mark which has to be removed from the concrete.

COST AND VALUE OF CONCRETE PAVEMENTS.

By J. H. Chubb.*

Concrete, one of the oldest and most valuable of the materials of construction, has been used for years as the base or foundation for pavements having some form of brick, block or asphalt wearing surface, but it was not until in comparatively recent years, or until practically everything else had been tried, that this material was used throughout in the construction of street pavements. Just why engineers and those dealing with the perplexing paving problems have been so slow in recognizing the value of this material for wearing surfaces is not known, but the fact remains that, in this country at least, it was not until 1893 that a pavement with a concrete wearing surface—a true concrete pavement—was constructed.

In an effort to obtain a reliable data on the cost and value of concrete pavements, information pertaining to the work as constructed in this country and in Canada has been collated. This type of pavement is just emerging from the experimental stage, and it is quite natural that there should have been a great variation in the method of construction, which has materially affected the value of these pavements. The experience of others and what has actually been accomplished in the way of construction serves as a guide or basis for estimating the cost of any new form of construction, but to simply state that such a pavement cost so much and was or was not satisfactory, without knowing of what and how it was constructed, would be of but little value; so in dealing with this subject it will be necessary to give some consideration to methods of construction.

About twenty years ago, wide concrete gutters were laid on the main street of Bellefontaine, Ohio. These gutters really served as a pavement next to the curb, and after several years of exceptionally hard usage showed so little wear and gave such

* Assistant Inspecting Engineer Universal Portland Cement Company, Chicago, Ill.

splendid satisfaction that the city engineer decided to try this form of construction for street pavements.

The Bellefontaine pavements were probably the first to be laid in this country, and a short description of the method of construction, and a word concerning the present condition of the work, will be of interest. The streets selected for this experimental pavement were those surrounding the court house block, two of which are quite narrow and two full width streets. The two narrow streets were paved during the summer of 1893 and the remaining two in October and November, 1894.

The pavement proper consists of a 4-inch Portland cement concrete base and a 2-inch wearing surface, the base being a 1:4 machine mixed gravel concrete and the top a 1:1 mixture of cement and screened bank sand. The materials were mixed in a screw or worm mixer 14 ft. long, on each side of which was a long rectangular box for measuring the aggregates. The sand or gravel, as the case may be, was placed in the bottom of the box, the proper amount of cement spread evenly over the aggregate and the mass shoveled from the box into the mixer. The concrete for the base and wearing surface was mixed quite dry and well tamped into place, the men laying the top following closely behind those laying the base. Starting at one curb the concrete was laid in strips 5 ft. wide, extending the full length of the area paved, these strips being cut into blocks 5 ft. square; that is, the pavement was really constructed in blocks and has wide, well-defined joints 5 ft. apart running at right angles and parallel to the axis of the street. No expansion joints were used. After thoroughly tamping the top, it was sprinkled with water and given a smooth sidewalk finish with a steel trowel. To afford a footing for horses the surface, on the two narrow streets, was marked into blocks 4 in. square by V-shaped grooves about half an inch wide and half an inch deep. On the other streets the surface was pitted with a toothed roller, giving it the appearance of a Nelsonville paving block.

After fifteen years of service the pavements are as a whole in a remarkably good condition, and with the exception of the wear along the longitudinal joints the surface shows but little the effect of traffic. Had these longitudinal joints been eliminated,

the work would to-day be in a first-class condition, as the joints at right angles to the curb show no appreciable wear. The surface markings have been erased in places, but with this exception the general surface is as good as the day it was placed.

These pavements were laid by contract at a cost to the city of $2.25 per square yard, including curb and drains. In 1900 the population of Bellefontaine was 6,550, which gives some idea of the amount of traffic to which these streets have been subjected.

The next city to experiment with concrete pavements was Richmond, Ind. A short, narrow alley was paved there in 1896. The pavement was laid and finished in very much the same manner as the Bellefontaine pavements, and with the exception of a slight unevenness in the surface of the blocks, due to a settlement in the foundation, shows practically no wear. Three additional alleys were paved in 1901, and every year since then a small amount of concrete pavement has been laid in Richmond. In fact, concrete has practically been adopted there as a standard for alley construction, as the cost is less than for any other suitable pavement.

Since 1900 a large amount of concrete pavement has been laid throughout the country, but with the exception of comparatively small areas in a few cities, most of the work has been done by two companies controlling patented methods of construction. These two patented systems are radically different as to method of construction, and a short description of a piece of work constructed according to each system will answer in a general way for all work laid by these companies.

What is known as the "Hassam Pavement" has been laid during the past three years in a number of cities in the States along the Atlantic Coast, and a description of a pavement at Summerville, Mass., will answer for pavements of this type.

The street was excavated to a depth of 6 in. below the grade line and rolled to the proper section. Upon this sub-grade was placed a layer of 1¼ to 2½ ins. of crushed stone, which, after thoroughly rolling to a surface 2 ins. below the finished grade of the street, was treated with a grout composed of one part cement and three parts fine sand. The grouting and rolling

were continued until the voids in the stone were well filled. The wearing surface consisted of a 2-in. layer of crushed trap rock. This was first rolled and then grouted with a thin grout composed of one part cement and two parts sand. For the finish, a thick grout of one part cement, one part sand, and one part pea-sized trap rock was poured on and brushed over the surface. The pavement was rolled to an even surface, allowed to harden for six days and was then ready for traffic. Expansion joints 1 in. wide filled with tar were provided at the curbs and placed across the street every 100 ft. Some 26,000 sq. yds. of pavement were laid at a contract price of $1.65 per sq. yd. Granite block pavement costs about $2.35, asphalt about $3.80 and vitrified brick about $2.75 per sq. yd. in Summerville.

The other patented pavement is what is known as the "Blome Company Granitoid Concrete Blocked Pavement" and has been laid in a number of cities throughout the country. In 1906-07 the approaches to the new highway bridge over the Potomac River at Washington, D. C., were paved with this pavement. This is a representative example of the Blome pavement and was constructed about as follows:

A suitable sub-grade was prepared and brought to the required section, 7 in. below the finished surface of the street. The pavement proper consists of a 5½ in. concrete base composed of one part cement, three parts sand, and five parts aggregate, ½ to 2 in. crusher run, the concrete being deposited in sections extending across the full width of the street. Before the base began to harden it was finished with a wearing surface 1½ in. thick, composed of two parts cement and three parts crushed granite screenings, all of which passed a No. 4 mesh, and from which the dust had been removed. Before the wearing surface hardened it was marked off into blocks about 4 x 9 ins., the 9 in. dimension being perpendicular to the curb. The block markings or grooves are about half an inch wide and one-quarter of an inch deep, with rounded edges. As a final finish, the surface before it had hardened was brushed with a stiff brush, so that it would not be too smooth or slippery. Expansion joints, about 1 in. wide, were placed 50 ft. apart, the joints being filled with a suitable pitch or asphaltum. About 15,000 sq. yds. of pavement were laid at an average cost of $2.00 per sq. yd. The

pavement is subjected to very heavy traffic, mostly heavy wagons hauling brick, and, while it shows some wear and has been repaired, those in charge of the streets in Washington consider that nothing but a granite block on a concrete foundation would have worn any better.

As to the cost of concrete pavements, there is comparatively little data available, but the contract price for which this pavement has been laid in a number of cities, together with the cost in the same cities of other pavements, supplies some information on this question. The cost, of course, varies according to the price of material and labor, and depends very much upon the method of construction and character of the foundation upon which the pavement is laid.

Windsor, Ontario, at the beginning of last year, had some 20,500 yds. of concrete pavement that were laid by contract at a cost to the city of from 99 cts. to $1.15 per sq. yd. Concrete curb cost 38 cts. per lineal foot, making the total cost for a 28 ft. street from $1.23 3/7 to $1.39 3/7 per sq. yd. The pavement consisted of a 4 in. hand-mixed concrete base, a 1:3:7 mix Portland cement, sand and ¼ to 3 in. crushed limestone. Two different wearing surfaces were used. On some streets the 4 in. concrete base was covered with 2 ins. of 1:2:4 gravel concrete, and on the other streets a layer of 1:2:4 gravel concrete, 1½ ins. thick, was covered with half an inch of 1:2 sand mortar. The cost of the pavement per square yard was divided as follows:

Base 4 ins. of 1:3:7 stone concrete	$0.57	
Top 2 ins. of 1:2:4 gravel concrete	.32	
Excavation	.10	$0.99
Base 4 ins. of 1:3:7 stone concrete	$0.66	
Top 1½ ins. of 1:2:4 and ½ in. of a 1:2 mortar	.39	
Excavation	.10	$1.15

The cost of material and labor was about as follows:

Portland Cement	$2.05
River sand, per cubic yard	1.15
Screened gravel, per cubic yard	1.25
Crushed limestone (ton)	1.15
Common labor	$1.75 to 2.00

At this cost of materials and labor, the contractor made a fair profit on the work done at $1.15 per sq. yd., but any profit at 99 cts. per sq. yd. is questionable, according to a former city engineer who furnished this data. These pavements are a great improvement over the macadam pavements constructed in Windsor at a cost of about $1.10 per sq. yd., but, I understand, have not been entirely satisfactory.

In Richmond, Ind., the contract price for this class of work has varied between $1.62, which was the cost of the first pavement laid in 1896, and $1.06, the contract price for which two short alleys were paved during the past year. Most of the pavements there consist of a 5 in. 1:2:5 concrete base and 1½ in. wearing surface of one part cement to two parts sand, or one part cement to one part sand and one part stone screenings. The surface is not marked in any way; simply floated with a steel trowel and raised with a cork float. Most of the pavement is in the business section of the city and all of it is in good condition. The present city engineer places concrete pavement in the same class with brick and when laid in a first-class manner considers it suitable for places where brick would be proper. The lowest price for which brick pavement has been laid in Richmond is about $2.00 per sq. yd.

In 1907, as an experiment, a small amount of concrete pavement was laid in Jackson, Mich. The pavement was laid on a wide street used largely for heavy teaming and has probably been subjected to the heaviest traffic of a city of 25,000. The pavement laid on a 4 in. gravel sub-base consists of a 6 in. gravel concrete base of a 1:7 mix, and a 4 in. wearing surface, one part cement to three parts Wisconsin granite. The work was done by a local contractor at a cost of $1.70 per sq. yd. The pavement to-day is in first-class condition and, according to the contractor who did the work, looks as though it would last for fifty years.

One of the first cities to use concrete as a paving material was Toronto, Canada, where in 1899 a small amount of this type of pavement was constructed. The asphalt pavements between the car-tracks on a street subjected to heavy traffic had gone to pieces, and, instead of resurfacing with asphalt, a new

wearing surface of concrete was laid on the old concrete base. This concrete top was composed of one part cement, one-half part sand and two parts crushed granite and was from 2½ to 3 ins. in thickness. Owing to the exceptionally heavy traffic, the work was not entirely satisfactory and the pavement had to be repaired after three years of service. A similar piece of work laid in 1900 on a residence street, has, however, given entire satisfaction and in 1903 a street subjected to heavy traffic was paved with concrete. The work was done by the City Engineering Department at a cost of $1.74 per sq. yd. for a 4 in. 1:3:7 broken stone concrete base and a 2½ in. wearing surface composed of one part cement to one part sand and three parts crushed granite. The following year a similar pavement, with a gravel and 2 in. tile drain, was constructed at a cost of $1.92 per sq. yd.

A longitudinal expansion joint three-quarters of an inch wide was placed down the center of the Toronto pavements, and, except for a slight chipping of the edges of the expansion joints, the pavements to-day are in very good condition.

In Toronto, asphalt and bitulithic pavements cost $2.25 per sq. yd., the former laid on a 6 in. and the latter on a 4 in. 1:3:7 concrete base. Vitrified brick cost $2.55 on a 6 in. concrete base and $2.25 on a 4 in. concrete base, and granite block on a 6 in. concrete base $3.50 per sq. yd.

At LeMars, Iowa, a small amount of concrete pavement was laid in 1904, and a careful inspection of this work shows it to be in better condition than an adjoining brick pavement laid about the same time. The pavement consisted of a 5 in. base composed of one part cement to six parts gravel and a 1½ in. wearing surface of a 1:2 mixture with coarse sand. This pavement was laid at a cost of $1.25 per sq. yd., while ten blocks of brick pavement laid the same season cost $2.08 per sq. yd. The cost of gravel was about 75 cts. per cu. yd. and of cement about $2.00 per barrel. The cost of grading was practically eliminated, as the dirt was sold for nearly enough to pay for the work.

Denver, Col., has a number of alleys paved with concrete, and this pavement is also used by the Denver Tramway Company

for paving between its rails and tracks. Four years ago there were some 30,000 sq. yds. of this pavement in use in alleys throughout the city, some of which are subjected to heavy traffic, and to-day the pavement is, I understand, in excellent condition.

The cost of a 4 in. 1:3:6 concrete pavement, finished with 2 ins. of 1:2:4 concrete, has ranged from $1.08 to $1.27 per sq. yd. Asphalt pavement in Denver cost about $3.47 per sq. yd., in 1907.

The City of Panama had over two miles of streets paved with concrete during 1906 and 1907, at a cost of about $2.00 per sq. yd., as against over $4.00 per sq. yd. for brick. The pavement, laid in alternate sections about 10 ft. wide, consists of 5 ins. of a 1:2½:5 concrete which was mixed rather wet, tamped until mortar flushed to the surface, and then finished with a trowel. For stone, the old cobbles which formerly paved the street were crushed in a portable crusher. Owing to the method of construction and the uniform tropical temperature, expansion joints were not considered necessary.

A small stretch of concrete pavement, 138 ft. long by 36 ft. wide, was laid at Allentown, Pa., during July, 1908. The street was excavated to a depth of 5 ins., and rolled with a steam roller. Upon this foundation was placed 5 ins. of hand-mixed concrete, one part cement to seven parts crushed stone The top or wearing surface consists of 1 in. of a 1:2 mixture of cement and ground granite passing a ¼ in. mesh. Expansion joints ¾ in. wide were placed along the curbs and a similar joint across the street 79 ft. from the ends. The surface was not blocked or marked in any way; simply roughened with a coarse reed brush. A gang of twenty men laid this pavement in three days and the cost of the work was $1.40 per sq. yd.

Bozeman, Montana, has some 25,700 sq. yds. of concrete pavement laid during the fall of 1908 by contract at a total cost, including all items, of $2.28 per sq. yd. Excavation was figured at 50 cts. per cu. yd., gravel fill $1.25 per cu. yd. and the pavement proper, not including the above items, $1.95 per sq. yd. Cement cost about $2.40 per barrel, sand and gravel $2.00 and $1.25, respectively, and common labor $2.50 for an 8-hour day. The street was excavated, rolled to the required section and a 3 in.

gravel sub-base laid over the area where no gravel foundation was found. The pavement, laid in alternate blocks 10 ft. square, with sides perpendicular to and parallel with the curb, consists of a 5½ in. concrete base, one part cement to six parts gravel, and a 1½ in. wearing surface, one part cement, one part crushed boulders or pea gravel through a ½ in. mesh, and one part clean, coarse sand. The surface was marked off and finished in very much the same manner as described for the Washington pavement, and

FIG. 1.—CONCRETE PAVEMENT AT BOZEMAN, MONTANA.

expansion joints placed across the street every 100 ft. and also along the curbs. (See Fig. 1.)

In Chicago there are a great many thousand square yards of concrete pavements subjected to all conditions of traffic, from the comparatively light on alleys and streets in the residence district to the heaviest on the streets adjacent to the large manufacturing and industrial plants. At the Hawthorne plant of the Western Electric Company, 48th Avenue and 24th Street, are some 40,000 sq. yds. of this pavement, most of which has been in use for four or five years, and it is all in first-class condition. Not one cent

has been expended for repairs, and they have found it to be the most suitable and cheapest pavement to construct and maintain.

During the spring of 1905 quite an extensive stretch of pavement was laid for Armour and Company on a street adjacent to their main packing plants at the Union Stock Yards. This pavement is subjected to heavy traffic from large packing plants in the immediate vicinity, is giving splendid service and is considered to be almost as noiseless as asphalt and much more sanitary than brick or block pavements. The pavements at the Western Electric Company and at the Union Stock Yards are very much alike and similar in general construction to the Washington pavements. The cost of the former, I understand, was from $1.80 to $2.20 per sq. yd., depending upon the depth of sub-base or fill, and of the latter, about $1.75 per sq. yd.

A large amount of concrete pavement was also laid during the fall of 1905 for Sears, Roebuck and Company at their mammoth plant on Harvard Street, Chicago. The pavement consists of a 6 in. 1:3:4 concrete base, cement, torpedo sand and crushed stone, and a 1½ in. wearing surface composed of five parts cement to seven parts granite screenings through a ¼ inch mesh. The surface was marked off into blocks about 4 by 10 ins., with grooves about ½ in. deep and ¼ in. wide, and expansion joints were placed every 24 ft. across the pavement and at the curbs. With the exception of some long cracks that have appeared at the crown in a number of places, the pavement is in very good condition, notwithstanding the fact that it is subjected to exceptionally heavy traffic, probably as heavy as on any street in Chicago outside the "loop district." The cracks in this pavement are undoubtedly due to the fact that it was laid on a comparatively deep, new clay fill and to the presence of a tunnel, carrying steam pipes, directly beneath the pavement at the center of the street, the cracks in most places being directly over the tunnel.

Examples of this type of pavement may also be seen in a number of other places in Chicago on streets and alleys, where it has been laid at the request of adjoining property owners by private contract at a less cost than any other suitable pavement. Last year in Chicago asphalt pavement cost about $2.03, creosote wood block $3.44 to $3.49, brick $2.55 and granite block $3.89 per sq. yd.

Probably the most extensive piece of concrete pavement in this country is at Gary, Indiana, where about three miles of pavement were laid during 1906 and 1907 on the principal streets of this modern city. (See Fig. 2.) Three years ago Gary was unknown, and to-day it is a city with a population of about 12,000. The construction of these pavements was among the first work undertaken and the greater part of the vast amount of material used in the building of this city was hauled over these pavements.

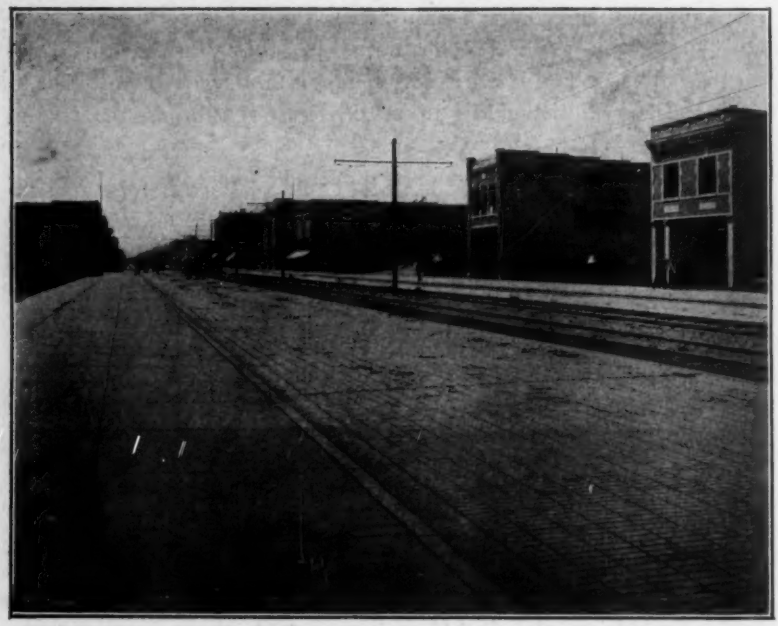


FIG. 2.—CONCRETE PAVEMENT, GARY, IND.

The traffic over them has been quite heavy, and they have worn remarkably well. The pavement proper was laid directly on the natural sand foundation and consists of a 5 in. 1:2:4 concrete base covered with a 2 in. wearing surface, five parts cement to about seven parts red granite screenings. The surface was marked off and finished in about the same manner as described for the Washington pavements, and the cost of the work was in the neighborhood of $2.00 per sq. yd.

New Orleans has eleven blocks of concrete pavement quite similar to the Washington pavement, the work having been completed the latter part of 1908 at an average cost of about $2.95 per sq. yd. This high cost was due to the fact that the crushed stone used in the 1¾ in. wearing surface cost about $3.50 per cu. yd., and for the further reason that more than one-half the cost of the pavement was borne by the city and paid for in interest bearing paving certificates worth about 85 cts. on the dollar. Concrete pavements have been laid in Grand Rapids, Michigan, at $1.50 to $1.78 per sq. yd. Kalamazoo, Michigan, has some 10,000 sq. yds. of this pavement, laid at a contract price of $1.74½ per sq. yd. Hancock, Michigan, reports 7,900 sq. yds. costing $2.20½, and Sioux Falls some 6,000 sq. yds. costing about $1.92 per sq. yd.

This type of pavement has been constructed in a number of other cities and towns, but what has been said concerning the cost and method of construction applies in a general way to the work as laid throughout the country.

From the data presented it will be seen that there has been a marked variation in the methods of construction. The thickness of the base has varied from 4 to 6 ins., practically every mixture from a 1:3:7 to a 1:2:4 hand or machine mixed concrete has been used, and the base has also been formed by filling the voids in a layer of stone with a cement grout. The pavements have been laid in blocks or sections from 5 ft. square up to sections the full width of the street and 100 ft. long. Expansion joints have been placed, in some cases, across the street, down the center and at the curbs; in other cases no expansion joints were used. The joints across the street have been placed from 24 to 100 ft. apart, and for fillers ordinary coal tar pitch and specially prepared asphaltic compounds have been used.

The greatest variation, however, is to be found in the construction of the wearing surface, and it would be difficult to conceive of any variation in the method of laying, finishing and marking the wearing surface that has not been tried. Pavements have been laid with no separate wearing surface, and with wearing surfaces of from 1 to 4 ins. of about every mixture from a 1:1 mortar, with different sands and stone screenings, to a

1:2:4 concrete. In some cases the surface has been given a smooth trowel finish, or a brush finish, and left in this condition; in others the smooth or brushed surfaces have been marked into square or rectangular blocks by grooving with grooves of various shapes, widths and depths, these surface markings being either perpendicular and parallel to the axis of or running diagonally across the street.

Considering the great variation in the method of construction it is not surprising that these pavements have been a success in some places and a failure in others. Pavements that would not answer for sidewalks have been constructed and expected to withstand the abuse of heavy traffic, and such construction has served to discourage the use of concrete as a paving material and to create a false impression as to its value for this class of work.

Concrete pavements have been laid by contract at a cost of from 99 cents to $2.92 per sq. yd. The former figure is undoubtedly too low for first-class construction even under the most favorable conditions, and $2.92, the cost per sq. yd. of the New Orleans pavement, is high, owing to local conditions. Considering the cost of material and labor and the method of construction, the estimated cost of $1.95 per sq. yd. for the pavement proper as laid in Bozeman, Montana, is probably more representative of the cost of this type of pavement; if anything, a little high.

The expensive part of a brick, block or asphalt pavement is the wearing surface. In Chicago, for example, between 70 and 75 per cent. of the cost per sq. yd. of a brick pavement (not including excavation or fill) is for materials and labor in laying the wearing surface alone, and for granite block between 78 and 82 per cent. of the cost is represented in the wearing surface. In the construction of a concrete pavement a comparatively cheap but satisfactory material, and one that costs much less to lay, is substituted for these expensive wearing surfaces, which explains why this pavement can be constructed at a much less cost than for those now in general use. The saving in cost is in the wearing surface, for practically the same concrete base answers for each type of pavement.

A concrete pavement is easily and economically cleaned, and from a sanitary and æsthetic point of view is an ideal pave-

ment. Where properly laid, such a pavement offers a good foothold for horses, is very little, if at all, more slippery than brick or stone block, and certainly less so than asphalt or wood block. Its resistance to traction is probably less than for any other pavement, and, while it is not as noiseless as asphalt or wood block, is superior to brick and stone blocks in this respect.

Such pavements are probably not adapted to the heaviest traffic of our largest cities, but may be considered as suitable in all places where brick, wood block or asphalt would be proper; and adapted to all conditions of traffic except that demanding stone block. Concrete is the ideal material for the paving of residence streets, of alleys, courts and squares, and in general makes an excellent intermediate pavement, as to cost and durability, between the stone block pavement of heavy traveled streets and the macadam of our country roads.

Where properly constructed with suitable materials the concrete pavement has been a success, and a careful inspection of the pavements as laid in a number of our principal cities and towns will, I believe, convince the most skeptical of the value of concrete as a paving material.

REPORT OF COMMITTEE ON SIDEWALKS, STREETS AND FLOORS.

By W. W. Schouler, Chairman.

The Committee presents herewith revisions in the Standard Specifications for Portland Cement Sidewalks and a Proposed Standard Specification for Portland Cement Roads.

Cement sidewalk construction should receive the most careful consideration of the Association as the condition and wearing qualities of cement sidewalks, all over the country, are under the direct observation of more people vitally interested than any other form of concrete construction. The specifications adopted at the last convention should have the most searching scrutiny and trial on the part of sidewalk contractors. The Committee realizes the importance and responsibility of an attempt to frame a specification applicable to the country at large, covering such variable and numerous climatic conditions. The experience of sidewalk contractors in the use of these specifications in the various sections of the country, if brought to the attention of the Committee would prove of invaluable aid in its work.

The efforts of the Committee to have our Standard Specifications adopted by the various municipalities has met with varied success. In a great many instances the specifications have been adopted with slight modifications but the revised specifications as herewith presented should obviate such modifications.

The Committee has had called to its attention the question of incorporating in the specifications a dry mixture for sidewalks where the finishing coat is tamped on so that it will not break from the body of the concrete. Contractors having used this method should communicate their experience to the Committee.

In the matter of the Proposed Specifications for Portland Cement Roads, the Committee has investigated the specifications covering the various methods of construction thus far used, and submits herewith tentative specifications for cement roadway construction.

Note.—Discussion on Sidewalks, p. 382; on Roads, 399.—Ed.

STANDARD NO. 2.

NATIONAL ASSOCIATION OF CEMENT USERS.

PHILADELPHIA, PA.

STANDARD SPECIFICATIONS FOR PORTLAND CEMENT SIDEWALKS.

ADOPTED JANUARY, 1908.
REVISED JANUARY, 1909.

MATERIALS.

1. **Cement.** The cement shall meet the requirements of the specifications for Portland cement of the American Society for Testing Materials, and adopted by this Association (Standard No. 1), January, 1906.

AGGREGATES.

2. **Fine Aggregates.** *Fine Aggregate* shall consist of sand, crushed stone, or gravel screenings, graded from fine to coarse, passing when dry a screen having ¼-in. diameter holes, shall be preferably of silicious materials, clean, coarse, free from vegetable loam or other deleterious matter, and not more than 6 per cent. shall pass a sieve having 100 meshes per linear inch.

Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets shall show a tensile strength of at least 70 per cent. of the strength of 1 : 3 mortar of the same consistency made with the same cement and standard Ottawa sand.

3. **Coarse Aggregates.** *Coarse Aggregate* shall consist of inert material, graded in size, such as crushed stone or gravel, which is retained on a screen having ¼-in. diameter holes, shall be clean, hard, durable, and free from all deleterious materials. Aggregates containing soft, flat or elongated particles, shall be excluded.

The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not prevent the concrete fully filling all parts of the forms. The size of the coarse aggregate shall be such as to pass a 1¼-in. ring.

4. Water. Water shall be clean, free from oil, acid, strong alkalies, or vegetable matter.

FORMS.

5. Material. Forms shall be free from warp, and of sufficient strength to resist springing out of shape. All mortar and dirt shall be removed from forms that have been previously used.

6. Setting. The forms shall be well staked to the established lines and grades, and their upper edges shall conform with finished grade of the walk, which shall have sufficient rise from the curb to provide proper drainage; but this rise shall not exceed three-eighths (⅜) of an inch per foot, except where such rise shall parallel the length of the walk.

7. Wetting. All forms shall be thoroughly wetted before any material is deposited against them.

SIZE AND THICKNESS OF SLABS.

8. Size. Slabs without reinforcement shall not contain more than 36 square feet or have any dimension greater than 6 feet. For greater area, slabs shall be reinforced with one-quarter (¼) inch steel rods, not more than nine (9) inches apart, or other reinforcement equally as strong.

9. Thickness. The minimum thickness of the pavement shall not be less than four (4) inches.

SUB-BASE.

10. Preparation. The sub-base shall be thoroughly rammed, and all soft spots removed and replaced by some suitable hard material.

11. Fills. When a fill exceeding one foot in thickness is required, it shall be thoroughly compacted by flooding and tamping in layers of not exceeding six (6) inches in thickness, and shall have a slope of not less than one to one and a half (1 : 1½).

The top of all fills shall extend at least 12 inches beyond the sidewalk.

12. **Wetting.** While compacting, the sub-base shall be thoroughly wetted and shall be maintained in that condition until the concrete is deposited.

BASE.

13. **Proportions.** The concrete for the base shall be so proportioned that the cement shall overfill the voids* in the fine aggregate by at least five (5) per cent., and the mortar shall overfill the voids in the coarse aggregate by at least ten (10) per cent. The proportions shall not exceed one (1) part of cement to eight (8) parts of the fine and coarse aggregates.

14. **Voids.** When the voids are not determined, the concrete shall have the proportions of one (1) part cement, three (3) parts fine aggregates and five (5) parts coarse aggregates. A sack of cement (94 pounds) shall be considered to have a volume of one (1) cubic foot.

MIXING.

15. **Mixing.** The ingredients of concrete shall be thoroughly mixed to the desired consistency, and the mixing shall continue until the cement is uniformly distributed and the mass is uniform in color and homogeneous.

a. Measuring Proportions. Methods of measurement of the proportions of the various ingredients including the water, shall be used which will secure separate uniform measurements at all times.

**To determine voids, fill a vessel with sand and let net weight of sand equal B. Fill same vessel with water and let net weight of water equal A.*

$$\text{Per cent. voids} = \frac{A \times 2.65 - B}{A \times 2.65} \times 100$$

This formula may also be used in determining voids in crushed stone and screenings by substituting for 2.65 the specific gravity of the stone.

The following is a more simple method for determining voids in coarse aggregate. Fill a vessel with the aggregate and let net weight equal B. Add water slowly until it just appears on the surface and weigh. Let net weight equal A. Fill same vessel with water and let net weight equal C.

$$\text{Per cent. voids} = \frac{A - B}{C} \times 100.$$

Use a vessel of not less than one-half (½) cubic foot capacity. The larger the vessel the more accurate the result.

b. Machine Mixing. When the conditions will permit, a machine mixer of a type which insures the proper mixing of the materials throughout the mass shall be used.

c. Hand Mixing. When it is necessary to mix by hand, the mixing shall be on a water-tight platform and the materials shall be turned until they are homogeneous in appearance and color.

d. Consistency. The materials shall be mixed wet enough to produce a concrete of such a consistency as will flush readily under light tamping, and which, on the other hand, can be conveyed from the mixer to the forms without separation of the coarse aggregate from the mortar.

16. Retempering. *e. Retempering.* Retempering mortar or concrete, *i. e.*, remixing with water after it has partially set, shall not be permitted.

PLACING OF CONCRETE.

17. Placing. *a. Methods.* After the addition of water the mix shall be handled rapidly to the place of final deposit, and under no circumstances shall concrete be used that has partially set.

b. Freezing Weather. The concrete shall not be mixed or deposited at a freezing temperature unless special precautions are taken to avoid the use of materials containing frost or covered with ice crystals, and in providing means to prevent the concrete from freezing after being placed in position and until it has thoroughly hardened.

18. Protection. Sidewalks shall be laid in such a manner as to insure the protection of the pavement from injury due to changes in foundations or from contraction and expansion.

Workmen shall not be permitted to walk on freshly laid concrete, and where sand or dust collects on the base it shall be carefully removed before the wearing surface is applied.

WEARING SURFACE.

19. Thickness. The wearing course shall have a thickness of a least one (1) inch.

20. Mixing. The wearing surface shall be mixed in the same manner as the mortar for the base, the proportion one (1) cement to two (2) of fine aggregate, and it shall be of such consistency as

will not require tamping, but will be readily floated with a straight-edge.

The wearing surface shall be spread on the base immediately after mixing, and in no case shall more than fifty (50) minutes elapse between the time that the concrete for the base is mixed and the time that the wearing course is floated. 21. **Depositing.**

After being worked to an approximately true surface, the slab markings shall be made directly over the joints in the base with a tool which shall cut clear through to the base and completely separate the wearing courses of adjacent slabs. 22. **Marking.**

The slabs shall be rounded on all surface edges to a radius of not less than one-half (½) inch. 23. **Edges.**

When required, the surface shall be troweled smooth. 24. **Troweling.**

The application of neat cement to the surface in order to hasten the hardening is prohibited.

On grades exceeding five (5) per cent., the surface shall be roughened. This may be done by the use of a grooving tool, toothed roller, brush, wooden float or other suitable tool; or by working coarse sand or screenings into the surface. 25. **Roughening Wearing Surface.**

Where color is used it shall be incorporated uniformly and the quantity and quality shall be such as to not impair the strength of the wearing surface. 26. **Color.**

SINGLE-COAT WORK.

Single-coat work shall be composed of one part of cement, two parts of fine aggregate and three parts of coarse aggregate, and the slabs separated as provided for in the specifications for two-coat work. 27. **Proportions.**

The concrete shall be firmly compacted by tamping and evenly struck off and smoothed to the top of the form. Then, with a suitable tool the coarser particles of the concrete shall be tamped to a depth which will permit of finishing the walk as under "Wearing Surface." 28. **Finishing.**

PROTECTION AND GRADING.

When completed, the walk shall be kept moist and protected from traffic and the elements for at least three days. 29. **Protection.**

Grading after the walks are ready for use should be on 30. **Grading.**

the curb side of the sidewalk, one and one-half (1½) inches lower than the sidewalk, and not less than one-quarter (¼) inch to the foot fall towards the curb or gutter. On the property side of the walk the ground should be graded back at least two (2) feet and not lower than the walk; this will insure the frost throwing the walk alike on both sides.

CURBS.

31. **Trench.** The trench shall be excavated to a depth not greater than the bottom of the curb and a width not greater than the thickness of the curb plus six (6) inches.

32. **Thickness.** The thickness of the curb shall not be less than six (6) inches.

33. **Wearing Surface.** After the forms are set about one (1) inch of wearing surface shall be placed on the inside of the curb form, then the concrete shall be deposited at one operation and firmly tamped to within one (1) inch of the top of forms. The top wearing surface shall then be placed and be of the same composition as that specified for sidewalks.

34. **Joints.** Joints shall be made three-fourths (¾) the depth of the curb, continuous with joints of the sidewalk and in no case more than six (6) feet apart.

35. **Faces.** The forms shall be removed as soon as practical and the faces finished at one operation floating down six (6) inches with a one to one mixture of cement and fine aggregate of sufficient thickness to produce a smooth surface.

36. **Gutter.** Where a combination curb and gutter is required, they shall be cast at the same time and finished at one operation.

National Association of Cement Users.

PHILADELPHIA, PA.

PROPOSED SPECIFICATIONS FOR PORTLAND CEMENT ROADS.

MATERIALS.

1. **Cement.** The cement shall meet the requirements of the specifications for Portland cement of the American Society for Testing Materials, and adopted by this Association (Standard No. 1), January, 1906.

AGGREGATES.

2. **Fine Aggregates.** *Fine Aggregate* shall consist of sand, crushed stone, or gravel screenings, graded from fine to coarse, passing when dry a screen having ¼-in. diameter holes, shall be of silicious materials, clean, coarse, free from vegetable loam or other deleterious matter, and not more than 6 per cent. shall pass a sieve having 100 meshes per linear inch.

Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets shall show a tensile strength of at least 70 per cent. of the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand.

3. **Coarse Aggregates.** *Coarse Aggregate* shall consist of inert material, graded in size such as crushed stone, or gravel, which is retained on a screen having ¼-in. diameter holes, shall be clean, hard, durable, and free from all deleterious materials. Aggregates containing soft, flat or elongated particles, shall be excluded.

The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not

prevent the concrete fully filling all parts of the forms. The size of the coarse aggregate shall be such as to pass a ¾-in. ring.

Where cinder concrete is permissible the cinders used as the coarse aggregate shall be composed of hard, clean, vitreous clinker, free from sulphides, unburned coal or ashes.

4. Water. Water shall be clean, free from oil, acid, strong alkalies, or vegetable matter.

FORMS.

5. Lumber. Forms shall be of lumber, free from warp, and not less than one and three-quarters (1¾) inches thick. All mortar and dirt shall be removed from forms that have been previously used.

6. Setting. The forms shall be well staked to the established lines and grades, and their upper edges shall conform with finished grade of the road, which shall have sufficient rise from the gutter to provide proper drainage; but this rise shall not exceed one-quarter (¼) of an inch per foot, except where such rise shall parallel the length of the road.

7. Cross Forms. At each division, cross forms shall be put in the full width of the roadway and at right angles to the side forms.

8. Wetting. All forms shall be thoroughly wetted before any material is deposited against them.

SUB-BASE.

9. Preparation. The sub-base shall be thoroughly rolled (with a 5-ton roller) to the proper slope—10 inches below the finished grade, and all soft spots removed and replaced by some suitable hard material.

10. Fills. When a fill exceeding one foot in thickness is required, it shall be thoroughly compacted by flooding and tamping in layers of not exceeding six (6) inches in thickness, and shall have a slope of not less than one to one and a half.

The top of all fills shall extend at least 24 inches beyond the roadway.

11. Wetting. While compacting, the sub-base shall be thoroughly wetted and shall be maintained in that condition until the concrete is deposited.

BASE.

12. Proportions. 13. Voids.

The concrete for the base shall be not less than 6 inches thick and so proportioned that the cement shall overfill the voids* in the fine aggregate by at least five (5) per cent., and the mortar shall overfill the voids in the coarse aggregate by at least ten (10) per cent. The proportions shall not exceed one (1) part of cement to eight (8) parts of the fine and coarse aggregates.

When the voids are not determined, the concrete shall have the proportions of one (1) part cement, three (3) parts fine aggregates and five (5) parts coarse aggregates. A sack of cement (94 pounds) shall be considered to have a volume of one (1) cubic foot.

MIXING.

14. Mixing.

The ingredients of concrete shall be thoroughly mixed to the desired consistency, and the mixing should continue until the cement is uniformly distributed and the mass is uniform in color and homogeneous, since maximum density and therefore greatest strength of a given mixture depends largely on thorough and complete mixing.

a. Measuring Proportions. Methods of measurement of the proportions of the various ingredients, including the water, shall be used, which will secure separate uniform measurements at all times.

b. Machine Mixing. When the conditions will permit, a machine mixer of a type which insures the proper proportioning of the materials throughout the mass should be used, since a more thorough and uniform consistency can be thus obtained.

** To determine voids, fill a vessel with sand and let net weight of sand equal B. Fill same vessel with water and let net weight of water equal A.*

$$\text{Per cent. voids} = \frac{A \times 2.65 - B}{A \times 2.65} \times 100.$$

This formula may also be used in determining voids in crushed stone and screenings by substituting for 2.65 the specific gravity of the stone.

The following is a more simple method for determining voids in coarse aggregate: Fill a vessel with the aggregate and let net weight equal B. Add water slowly until it just appears on the surface and weigh. Let net weight equal A. Fill same vessel with water and let net weight equal C.

$$\text{Per cent. voids} = \frac{A - B}{C} \times 100.$$

Use a vessel of not less than one-half (½) cubic foot capacity. The larger the vessel, the more accurate the result.

c. Hand Mixing. When it is necessary to mix by hand, the mixing should be on a water-tight platform and especial precautions should be taken to turn the materials until they are homogeneous in appearance and color.

d. Consistency. The materials shall be mixed wet enough to produce a concrete of such a consistency as will flow into the forms and about the metal reinforcement, and which, on the other hand, can be conveyed from the mixer to the forms without separation of the coarse aggregate from the mortar.

e. Retempering. Retempering mortar or concrete, *i. e.*, remixing with water after it has partially set, shall not be permitted.

PLACING OF CONCRETE.

a. Methods. Concrete after the addition of water to the mix shall be handled rapidly, and in as small masses as is practicable from the place of mixing to the place of final deposit, and under no circumstances should concrete be used that has partially set before final placing. A slow setting cement should be used when a long time is liable to occur between mixing and final placing.

When work is resumed, concrete previously placed shall be roughened, thoroughly cleansed of foreign material and laitance, drenched and slushed with a mortar consisting of one part Portland cement and not more than two parts fine aggregate.

The faces of concrete exposed to premature drying should be kept wet for a period of at least seven days.

b. Freezing Weather. The concrete shall not be mixed or deposited at a freezing temperature unless special precautions are taken to avoid the use of materials containing frost or covered with ice crystals, and in providing means to prevent the concrete from freezing after being placed in position and until it has thoroughly hardened.

15. Protection. Workmen shall not be permitted to walk on freshly laid concrete, and where sand or dust collects on the base it shall be carefully removed before the wearing surface is applied.

WEARING SURFACE.

16. Thickness. The wearing surface shall have a thickness of at least four (4) inches.

17. **Mixing.** The concrete shall be mixed in the same manner as the mortar for the base, but the proportion of one (1) part cement to three (3) parts of fine aggregate, and six (6) parts coarse aggregate, and it shall be of such consistency as will not require tamping, but will be readily floated with a straight-edge.

18. **Depositing.** The concrete shall be spread on the base immediately after mixing, and in no case shall more than fifty (50) minutes elapse between the time that the concrete for the base is mixed and the time that the wearing course is floated.

19. **Edges.** All surface edges shall be rounded to a radius of not less than one-quarter (¼) inch.

SINGLE COAT WORK.

20. **Proportions.** Single coat work shall be composed of one part of cement, two parts of fine aggregate and three parts of coarse aggregate.

21. **Finishing.** The concrete shall be firmly compacted by tamping and evenly struck off and smoothed to the top of the form. Then, with a suitable tool the coarser particles of the concrete shall be tamped to a depth which will permit a mortar finish.

PROTECTION AND GRADING.

22. **Protection.** When completed, the road shall be kept moist and protected from traffic and the elements for at least three weeks.

23. **Grading.** Grading after the roadways are ready for use should be on the curb side of the roadway, one and one-half (1½) inches lower than the roadway, and not less than one-quarter (¼) inch to the foot fall towards the curb or gutter. On each side of the road the ground should be graded back at least two (2) feet and not lower than the road; this will insure the frost throwing the road alike on both sides.

Respectfully submitted on behalf of the Committee.

W. W. SCHOULER,
Chairman.

Committee:
W. W. SCHOULER,
C. W. BOYNTON,
G. F. LILLIE,
GEORGE L. STANLEY,
N. P. WINCHELL.

DISCUSSION ON SIDEWALKS.

Mr. Boynton. MR. C. W. BOYNTON.—I have been asked to open the discussion on the Standard Specifications for Cement Sidewalks. In a general way the specifications should be more definite as to aggregates, and I am quite certain that this will add to their value.

There seems to be a diversity of opinion as to the necessity for a sub-base and the question of foundation. We should bear in mind that this Association is trying to draw up a specification that will satisfy as nearly as possible the various conditions met with in all sections of the country. We must not take the poorest natural condition and provide for that; neither must our specifications provide for construction under the most favorable conditions. We should endeavor to strike a medium, rather leaning toward the less favorable conditions at all times. There is more of a tendency on the part of the builder of sidewalks, the engineer, or a community in general to modify a specification down rather than up. Therefore, I believe it is the duty of this Association to make the specifications for sidewalks a little more rigid than would be required for the average condition. The specification should be one which will give, so far as possible, a good walk under practically all conditions and a first class walk under normal or average conditions. There are some localities that do not require a cinder foundation and drainage or other such refinements, but there are localities in which these things are a necessity. In a heavy clay soil artificial drainage is necessary, but where the soil is light and sandy the natural drainage is frequently sufficient.

Shortly after the last Annual Meeting I was in Nebraska and the people there were up in arms because the specifications had undertaken to provide for some sort of drainage. They said their soil did not require drainage and they should not be burdened with such a requirement. If they do not require drainage it is not necessary for them to use it, but at the same time if we should draw a specification to suit that particular locality, pro-

vision for drainage would be lacking where necessary and poor walks would result. The end that we are aiming for as cement users and those interested in the preparation of materials used in the building of walks is perfect work wherever it is possible to get it. The engineer in using a standard specification must exercise judgment, and where an engineer is not in charge the contractor must use judgment. There is too much of a tendency in every locality to build cheap walks rather than good ones. **Mr. Boynton.**

Referring to size of slabs and thickness of walk, I can see no advantage in varying the size and thickness for different classes of service, for instance, the specification says that in business sections walks should be of a certain thickness for a given size slab, and in residence districts they should be of a different size and thickness. I believe that a walk 4¾ ins. thick is light enough, also sufficiently heavy for ordinary service. To me it seems inconsistent to vary the thickness with the size of the slabs. If a walk 4¾ ins. thick is not sufficiently heavy for a particular service, the thickness should be increased regardless of the size of the slabs into which the walk is divided.

The specifications mention single coat work. I believe that a good walk can be built by this method. The material required is about the same, but there is a slight saving in labor. If the specifications are not weakened by a provision for single coat work I can see no objection to it, but do think it would be advisable to include it as an optional clause.

The last paragraph under Protection and Grading impresses me as being too broad. The contractor should not be required to do any more than is necessary to properly protect the walk and nothing more should be included in this specification. If the builder of the walk and the property owner wish to enter into an agreement for the grading of the lawn and parkway, the specifications for the sidewalk will not in any way interfere.

MR. W. W. SCHOULER.—When a sidewalk is laid honestly to the thickness suggested in the specification and cut right, I cannot understand why weather conditions or location should affect it at all. The same walk could be laid in Florida as in Oregon, if the blocks are supported the same as a flagstone. The guarantees called for by the average engineer and architect are **Mr. Schouler.**

Mr. Schouler. that there shall be no cracking for a period of five years, whereas the flagstone is not guaranteed over night. I cannot see why, when a sidewalk is laid as suggested, that it should need a porous foundation any more than a flagstone. Especially since it is known that the only reason sand or porous material is used under a flagstone is to have a uniform bed where the soil cannot be excavated so that a bluestone with an uneven surface will have a uniform bed all over. Consequently sand, coal dust or whatever is convenient to make a uniform bed, is used. Flagstone works down continually, about the thickness of the material under it, through the washing of the rain; but you will find cement walks seldom are raised by frost. If they come up at all it is on account of the root of a tree or if the joints are not large enough the walk may heave up in places from expansion. I have not seen any sidewalks set up in the summer that are affected by the frost in the winter, and I have made many observations. In Dansville, New York, there are seven miles of sidewalk laid right on the ground, and I have not been able to find a crack. The cost was 9 cts. a foot.

In the matter of drainage in a city, this is established by the curb. To drain the excavation underneath a sidewalk it was suggested last year that you connect it with the sewer. Streets usually have sidewalks before sewers. A gentleman from Ohio said that if he did not have a sewer in the street he would connect the excavation under the sidewalk with his cellar. I found afterwards that the lake was rising and falling about 2 ft. in his cellar, so it did not make much difference.

The reason cement sidewalks are slighted is largely because of the competition with bluestone, which is more apt to crack than cement from frost or any other cause. In order to get down to the cost of bluestone we have had to leave out cement. Now if we could get out the cinder foundation we can successfully compete with the bluestone men.

As to the size of blocks, I believe that 75 per cent. of the sidewalks, driveways and stable floors are 4 ins. thick and 50 per cent. of the sidewalks in the country are 4 ft. wide. The specifications call for blocks to be as many inches thick as they are feet wide and to be square. I have tried to lay sidewalks 6

and 8 ft. square, 4 ins. thick and frequently found they would crack; and it seems to me that to vary the thickness with the size is the safest. I do not think that a distinction should be made between the thickness of residence and business walks. **Mr. Schouler.**

Regarding the size of sand, I cannot mention any contractor who knows intelligently what proportion of sand will pass a 15-mesh and stand in a 20-mesh or *vice versa*. I tried to introduce these specifications in the city of Newark, N. J., and the City Engineer said immediately, "Omit the sand clause." He had no use for it. Good coarse sand, which a contractor can find most anywhere, is the best to use.

Someone mentioned the use of quicksand. I would not lay a sidewalk if I had nothing but quicksand to use, and I would expect poor results from using fine sand.

MR. W. F. WISELOGEL.—I do not agree with Mr. Schouler on the question of slabs. We all know that a residence sidewalk does not receive the hard usage of a business sidewalk. A residence sidewalk 4 ins. thick is heavy enough. However, a walk in front of a place of business where barrels and large trucks are handled, especially when a commercial drummer comes along with a trunk that weighs a ton or two and it is dumped down on the sidewalk, if that sidewalk has not sufficient thickness it will not stand. **Mr. Wiselogel.**

There is one thing we all should bear in mind and it is that people will expect a concrete sidewalk to have the same strength as a stone walk, not considering how long it has been down. A stone has had years to crystallize and becomes solid. A sidewalk, if it is down thirty days or three months at the outside, is supposed to be just as much of a stone as the natural stone. I claim it is not; it has not yet become a stone. Our engineers claim that it takes from five to ten years for an ordinary pier to crystallize and become hard all the way through. I know a case where a floor in a machine shop 8 ins. thick, had been down three years and in punching holes through for bolts, the first few inches were found to be hard. When getting down 5 ins. moisture was found in the concrete, and it was not as hard nor as strong as the top. In this case the concrete had not crystallized all the way through. It is not fair to expect a sidewalk to resist any

Mr. Wiselogel. misuse that it may fall heir to inside of a year after it is built. For that reason a sidewalk in front of a business block should be heavier and thicker than a residence sidewalk.

Now in the matter of drainage, I think that depends upon circumstances. I do know that on a clayey soil, on a heavy and wet soil, a walk freezes and it does heave. Possibly the stone might rise and go back, providing there is no obstruction when it comes back. I believe that a specification should be made to cover such conditions. We know that in the northern part of these United States, especially where the heavy timber grew, that the soil is sandy and light. It freezes, but does not heave. There a sub-base is not necessary. But where the ground is low and clayey there should be some way of preventing this heaving. And again, if the sub-base is of porous cinders, they will gather the moisture and also freeze, and if they freeze they will expand. Therefore it is necessary to drain the sidewalk.

Mr. Chandler. MR. DANA G. CHANDLER.—I have built sidewalks on the hardest kind of clay, where it was necessary to take a mattock and chip it up in order to get through. That walk to-day is just as good and even better than any walk I ever laid on a sub-base. I am always thorough in cutting the joints, using sand. The walk, it is very true, heaves, but it goes back. I have also built on sand and I have known of instances where the sidewalk heaved as badly on sand as on clay. It is my experience that if you are thorough in cutting your joints on clay soil you will have a good walk, as good as where a base is used.

Mr. Longacher. MR. P. T. LONGACHER.—I have laid something like twelve miles of sidewalk over three different soils. It was clay, wet and dry sand, and we had three different experiences. We found where we laid the sidewalk we used 3½ ins. of concrete and ¾ ins. top,—on dry sand and cut a 5 ft. walk into 4 ft. blocks, leaving at least from 11/16 to ⅜ in. joint, that we never had a bottom where it would heave. Where the ground was low and the water would stand under the walk, after freezing it would heave. We laid it on clay and after freezing it would heave. Some would go back and some would not.

We never bid on a sidewalk unless we go out and look over the ground. I laid a sidewalk about a half a mile long, having

sand soil on both ends of the walk, and in the middle portion black, loamy soil. About six months afterwards I had occasion to go over that sidewalk and could mark right on the sidewalk the place where the black ground commenced, because the light ground was hard. You could take a penknife and dig the walk over the wet black ground. I told the cement manufacturer that he had sold me a bad batch of cement. He soon convinced me that he had not and that it was the condition of the soil on which the sidewalk was laid. If I had used a cinder foundation or had the walk properly drained this would not have occurred. **Mr. Longacher.**

MR. C. W. CADWELL.—I have spoken each year at this convention on the drainage question, and I am just as thoroughly convinced now as ever that we must judge by local conditions to a great extent. I intend to omit the sub-foundation almost entirely. I do not think there is a town but that it has clay, sand or black loam soil. The specifications for the sidewalk around the Detroit postoffice were to excavate down 12 ins. over all. It was heavy clay soil, and at our suggestion it was cut down to 8 ins. over all. It was 54 ft. wide in places. It has been down ten or twelve years and it is as nice a walk as any man has ever seen. I bid on a walk in lower Canada, near Montreal, in which was required 23 ins. of excavation. The man that got the work was even with me at 23 cts. a ft. He lost money on that contract and that piece of work was the curse of the town. A few years after that they sent a delegation up to Detroit and Windsor to look over the walks there, and on returning changed their excavation to 2 ins. and are building their walks now for 11 cts., less than one-half. **Mr. Cadwell.**

I laid a walk about 900 ft. long from curb to curb. It ran nicely down a hill for about one-half of the way. At the lower end a banker lived with his brother and they wanted the walk a little different from the specifications, and at the upper end of their lots, about 200 ft. from the lower end, put in tile right close down and ran it about 3 ft. under the walk at the direct sewer fall. They filled this up to the level of the walk with brickbats and gravel. This is the poorest piece of work in that town as far as heaving is concerned. I have seen cracks 1½ ins. wide in winter-time. Right across the street there is a founda-

Mr. Cadwell. tion of 2 ins. of cinders under the walk, and it does not heave half as badly. The specifications called for 1 in. of sand or cinders. Why have any? I helped frame these specifications, and the only reason for putting in that 1 in. was, that if there is a high piece here and there and if there is not a sub-base, the water will have to raise clear over the walk and float away. If there is 1 or ½ in. of cinders it will give the seepage a chance to move off under the walk.

I build all the way from Indianapolis to Alpena, Michigan, and a long distance up in Canada, and I have not resorted to a heavy fill for fifteen years. I have just entered my nineteenth year in the sidewalk business and have made the following demonstration. In Walkerville quite a stir was made about not having enough filling. My specifications read that where it was necessary we were to put in a filling of 6 ins., and I did not find it necessary very often. The Board of Works said that they did not know what was going on. I finally asked them if they would allow us to make an experiment and said that we would lower the forms 1 or 2 ins. and scrape out every particle of fill and lay on the heavy clay soil. We would put this block down and they need not pay for five years. There was not very much filling there then. That portion of the walk is just about as good as the rest of it.

In building sidewalks we must go over clay, sand, black loam or anything else. I have put walks on black loam where you could jump on the soil and shake it for thirty feet around, and those walks are in splendid condition. I do not think it is in the foundation.

A Member. A MEMBER.—I have had twenty-six years' experience in building sidewalks in Western Canada and have tried every method under the sun. The condition of the soil is of great importance in building sidewalks. In our country there is a black loam, and I have found that the trouble is not so much with the heaving as with the breakage of sidewalks. The soil freezes under the sidewalk and it expands and contracts the walk, not heaves. I have had a great deal of trouble that way. Some eight or ten years ago I began to put ashes under the walk, not over 2 ins. thick, and since then I have never had a failure in

sidewalk work, either in a black soil or clay, and have fully made up my mind that it is not the heaving that breaks the walk, but it is the dirt freezing under the walk and not expanding the same as the cement. **A Member.**

Cinders will not freeze in a sidewalk. You can go out the coldest day, take up a block of sidewalk and it will be perfectly clean. When the soil is dry and freezes we would have no sidewalk break, but if the soil is wet and freezes to the sidewalk it will break nine times out of ten. I have never had a failure with cinders under the walk. I make my sidewalk 4 ins. thick and 5 ft. wide. The sand and the gravel come from the river and are used in about the proportions of one, two, three. I put expansion joints not more than 40 ft. apart and have built walks miles and miles long, 5 ft. wide, with not a check in them. I have learned that freshly burnt cement will expand 100 per cent. more than old cement that has aged, and have seen cement that has expanded so as to burst the barrels.

In regard to finishing, we never have any hair checks in our work. We make our top coat 2:3. I find that the cause of hair checks is dry cement and make the walk just as wet as possible so that the water will lie on the top.

MR. J. A. FOWLER.—Last November I built quite an expensive porch floor. It was accepted by an engineer who was an ex-commissioner of the county, the owner paid for the work and was well satisfied. A week later it had blisters an inch in size. Is there any way by which I can fix that floor? It was the first freeze of the season. **Mr. Fowler.**

MR. SCHOULER.—The only way you can fix that is to tear it up and do it over. **Mr. Schouler.**

MR. JOHN P. SCHUYLER.—In regard to the filling under the walk I have almost made up my mind that it is not necessary, at least to the extent most people claim. As a rule all government or state specifications for flag walks call for a filling or what is termed a cushion. I suppose it is in order to eliminate the different kinds of soil and material that are under the walk and to have a layer of one kind of material. Then if it freezes all points will rise the same and when the frost goes the walk will settle evenly. That is the only reason, I think, for filling under **Mr. Schuyler.**

Mr. Schuyler. the walk, and 1 or 2 ins. is sufficient. If there is clay in one place and stone or loam in another, it will not all freeze and heave alike, consequently it will not settle alike when the frost goes out. For that reason I think a little filling is good.

In regard to the top of walks, I have not heard anyone say whether they used an edge that was straight or whether they used one that was oval and gave the walk a crown. For the last two years I have made all of my walks crowning. Where the mixture is not strictly uniform some spots will be a trifle softer than others and will settle, allowing little cups to form on the walk. By giving a 4 or 5 ft. walk a crown of ¼ to ½ ins. this is prevented and the water will all run off, making the walk a great deal dryer and nicer. I find that people like the crowned walk a great deal better. Of course, there may not be more than 1/32 of an inch of water on the walk, but it looks more and ladies will drag their skirts and get them wet. In cold weather the water will stand and freeze and the walk will become icy. In finishing I think it is better to float the walks which makes them not nearly so smooth as when troweled. In wet weather they are not as slippery and, of course, in cold weather the ice will accumulate anyway.

Mr. Schouler. MR. SCHOULER.—In regard to crowning walks, private walks running from a front stoop to the street with a little fall, it is wise to crown, but certainly not a street walk, where you are supposed to shed all the water into the gutter by giving the walk, as the revised specifications suggest, a grade ⅜ of an inch to the foot. You get the same fall in every foot. Formerly city engineers specified ½ in. to the foot. Since cement walks have come into use they have modified it to ⅜ ins., but you certainly ought not to crown any street walks.

Mr. Schuyler. MR. SCHUYLER.—In the same case as Mr. Schouler states, I leave the outside of my walk about ¾ of an inch lower than the inside. Take a 4, 4½ or 5 ft. walk, I will use a straight edge 6 ft. long and give ½ in. crown to the 6 ft. The cement becomes more compact by using a tool to make the edge oval than it does in the center. It is more liable to be hollow in the center when you use a straight edge, without the greatest caution. It will settle a little and still give you an oval in the walk as well as the slant that the engineer calls for.

MR. CADWELL.—I believe in lots of water in concrete for the top coat. We float our top coat on sidewalks as a batter. I do not like to finish it too soon. The chances are if this surface is finished while the water is there, it will rise to the top, collect in pools under which the cement will sink, making it denser under that thin scale than in any other place. However, if after placing and striking off, the top coat is too wet to be properly troweled or floated, it is better to wait. I have delayed this operation till twelve or one o'clock at night to avoid finishing too soon. I know positively that the bringing up of puddles on the surface results in soft spots that will wear off and appear rough. The surface itself, no matter how hard the concrete, will absorb some moisture, especially if it is a rough surface, because the aggregate will absorb a certain amount of moisture. On the other hand, the concrete will absorb a certain amount of moisture and will take enough from the top coat to prevent an excess of water appearing and you get a better surface. We have had to go over these spots before they were too hard and take the cement off and float or trowel it again. **Mr. Cadwell.**

If there is quicksand in your top coat it will rise to the surface and eventually wear off. I had a long strip of walk to build and took the sand from a beach. In a day or so the walk began to wear off in spots, and I took some of the finest of that particular sand and made sample mortars. I could see in troweling that it would curl up right behind the trowel, and by watching it very closely on the work the finest particles of the sand could be noticed coming to the top. This showed that the quicksand comes to the top and it certainly will wear off.

The placing of a top surface on the base must be done in a business-like manner. I have taken walks with a hard surface and put a top surface on them not more than a quarter of an inch thick. In one case the top has been on for the last fifteen or sixteen years and I know it is in perfect condition to-day. But we have to be careful in doing it. Now in regard to placing the top on a walk that has been laid the day before. It is a bad thing to leave a walk unfinished over night or over Sunday except in the fall, when it is sometimes possible to satisfactorily finish such work. I cannot recall a walk I have laid in recent

Mr. Cadwell. years that was scaled, and when a walk gets in that condition I sweep off everything loose and make a thin grout, going over the concrete just prior to placing the top coat. However, not so far in advance that it will dry out before placing the top, which should be quite thin.

The bulging of walks seems to me to be the worst difficulty. It is not always due to lack of bond between the top and bottom, as I have, in several cases, removed and replaced an inch of surface and it remained in perfect condition for years. In making joints we use an iron knife about eighteen inches long and one-quarter of an inch thick, fill the joint with sand and tamp lightly.

A Member. A MEMBER.—I would like to ask why we have more expansion now than we did years ago?

Mr. Cadwell. MR. CADWELL.—Well, why is it? I know of a place where the sidewalk bulged up 9 ins. after it had been down fourteen years.

Mr. Welch. MR. CHARLES J. WELCH.—I have been building sidewalks for about seven years and up to the last three years never thought much about expansion joints; just kept our joints clear. I never put in an expansion strip. About three years ago, the first joint I put in, not more than six months elapsed before the walk expanded far enough to burst the curb. We never had a bit of trouble with the walks put in before that. Since that time we have been putting in expansion joints every 50 feet and fi'ling them with asphalt, and some of this bulged up, but not very much. On the other hand, a walk was laid six months ago, about 400 feet long, without expansion joints and there has been no bulging of the walk. I laid 200 ft. of walk about three years ago, and now the blocks bulge in the center. I would like to ask for an explanation of someone experienced in this line. The street was paved with brick and the expansion of the sidewalk broke the concrete curb from the top of the gutter, the curb and gutter being monolithic.

Mr. Schouler. MR. SCHOULER.—I have had quite a little experience in laying solid walks from the building to the curb on streets paved with brick and asphalt. In two or three walks about which I was very particular, a crack would occur about 3 ft. back from the

curb, and it seemed as though at that point the walk was lifted a little. The only way I can account for it is that the concrete underneath the brick pavement had pushed in the bottom of the curb, and the curb being part of the outside block had broken it in about the middle. The expansion of cement is less than one inch in 100 ft., and I cannot see how a walk 10 or 12 or 15 ft. wide could push the curb out. I imagine it might be due to the brick or the concrete in the street, that it shoved in the bottom of the curb, and it necessarily had to come out at the top. **Mr. Schouler.**

MR. CADWELL.—It is the narrow walk 4 or 5 ft. wide that shoves the curb off. A walk may be 1000 ft. long and if it will expand an inch in 100 ft., in 1000 ft. you have quite an expansion. We are not allowed to put a walk within 1 in. or 1½ ins. of the curb on any end where there is paved street or curb. I have had lots of cases, I should say over a hundred, where the walk bulged. In building walks for the last seven or eight years, I have noticed that they will push and break the curb in the paved streets. I think the reason for having more trouble now is that we have longer extensions of walks. Cement has become so universal and every street is paved from curb to curb. No matter how long a street is, if there is no street intersection, it expands and it will burst the curb on each end. That is one reason why we leave the space, regardless of the length of the street. **Mr. Cadwell.**

MR. GEORGE T. GRAVES.—In Kentucky we have never had any trouble with cutting joints; we put in a batch of concrete and place the top and then cut 4 ft. blocks. When stopping at night we leave a square joint to which we connect the next day as neatly as possible. In course of time the joint blocks will raise ¼ in. and there is a buckle in the walk showing the end of a day's work. **Mr. Graves.**

Under the walk we put 6 or 8 ins. of cinders, 3 ins. of concrete and 1 in. of top; mix of top 1 : 1½ or 2. The temperature ranges from 70 to 90 degrees in summer. But I find the same trouble in all seasons, down to within 40 degrees, from 40 to 90 degrees.

MR. F. S. PHIPPS.—In building walks in Missouri I always use the iron division plate. The plates are ¼ in. thick and 4 ins. **Mr. Phipps.**

Mr. Phipps. wide. I put down a 2 x 4 on the outside, and then place the division plate level with the 2 x 4. After the top is put in and troweled once, we remove the division plates, which leaves a ¼ in. joint. In making a 4 ft. walk I make my blocks 4 ft. square, a 5 ft. walk, 5 ft. square. I have never had any trouble with the breaking of curbs or buckling of the walks.

Mr. Schouler. MR. SCHOULER.—I would like to ask if anyone has had experience in laying sidewalks with a concrete mixer.

Mr. Cadwell. MR. CADWELL.—I have used a batch mixer for seven years. I have put down as high as $70,000 worth of sidewalks in a season and would not go back to hand mixing for any consideration. I do not see why we should go back to the hand mixing, as it would be taking a step backward, because we can put in 5,000 ft. a day with a good mixer and sixteen men.

Mr. Chandler. MR. CHANDLER.—I have had experience both ways, but cannot lay 1,400 sq. ft. a day with a mixer. The most I have ever done with three men and a mixer is 1,250 ft., when the boys were working on a little extra pay to get through Saturday night. I had occasion to remove some hand mixed blocks and also machine mixed; and you could readily see a difference, although I am very, very particular in hand mixing. I use a batch mixer and it saves me a lot of money.

Mr. Cadwell. MR. CADWELL.—In regard to walks and their cracking, what would make a walk crack within twenty-four hours after it was finished, open up cracks into which you could stick a knife? I cannot give any reason other than poor cement. It just cracks once in a while and you might have to take one or two blocks out. I do not think I ever had over two blocks where the cracking occurred inside of an hour after the walk was finished.

Mr. Bush. MR. R. G. BUSH.—Regarding the cracking of green cement, I believe it lies in the contraction. I have never had any trouble with the expanding of cement, but I have in the contraction of green cement. An inferior quality of cement expands on account of improper calcination. This is borne out by the case in which the cement kept in barrels swelled so as to burst the hoops. All cement and concrete work contracts when it is green.

Mr. Prince. MR. GEORGE C. PRINCE.—Often it is necessary to leave concrete and you cannot continue the work by reason of rain, etc.,

for perhaps two or three days. I always carry paper to cover it so as to keep the dust and dirt that are continually blowing over, from lodging on the concrete. I believe one very important point is to keep the concrete clean. Do not let your men walk on the concrete. There is always a lot of loose dirt and if we keep it off there will be less trouble. **Mr. Prince.**

I have obtained very good results from laying sidewalks in one operation. I use joints the same as in putting down two coat work. The metal plates are placed every 4 or 5 ft., the width of the walk, and the top and bottom coat are put down at one operation, using a wet mixture with the same amount of sand in the concrete as is used for the top coat. The saving in labor is about 20 per cent.

MR. GEORGE W. WINSHIP.—My method of making sidewalks is to tamp the under coat with sufficient moisture to rise to the top. Then the top coat is spread on the wet concrete immediately. **Mr. Winship.**

MR. S. B. MACAFEE.—We have always built our walks with a dry top and tamped the top surface thoroughly, then cut it off with a straight edge and float finish. **Mr. Macafee.**

MR. SCHOULER.—Do you not have to put in ½ in. more dry than wet material? **Mr. Schouler.**

MR. MACAFEE.—The loose material tamps down about 30 per cent., but as the concrete base has previously been tamped solid, we do not lose any of the top in that. There cannot be any more tamped top material used than when the top is put on wet and the water depended upon to compact the mass, as there is only the same amount of space to be filled either way. Our records of quantities of material used, which have been carefully kept for a number of years, show this very conclusively. We usually rod it two or three times. We have found that the time spent for the extra rodding is more than compensated for by the gain in time and labor required for the finishing. As soon as it is rodded the finisher floats it and finishes the edges and joints. **Mr. Macafee.**

MR. O. U. MIRACLE.—I would like to ask whether the members cover their walks as soon as the top coat is set sufficiently, either with sand or sawdust, to protect them from the hot sun. **Mr. Miracle.**

MR. SCHUYLER.—I cover the walks with pine board covers made of matched lumber. The covers are wider than the walk **Mr. Schuyler.**

Mr. Schuyler. and 10 or 12 ft. long. A walk will sweat in the hottest days in summer when covered in this way and the sweating of a walk is the best manner of hardening it. I keep the covers on the walk from 48 to 72 hours when I can, in sun and rain both.

Mr. Wiselogel. MR. WISELOGEL.—A party desired me to put down a sidewalk, making it slush, not tamping it at all, and when it was sufficiently set or enough water had evaporated, to put on the top. I did not think the walk would be good, but it was. Now in building a driveway or in covering any place where there is heavy teaming, I put the concrete down slush and give it a float finish, which always sets well. I think it is advisable to cover a walk during the hot sun.

Mr. Zeiser. MR. JOHN R. ZEISER (by letter).—In the interest of better sidewalk construction, I desire to call attention to the fact that in my opinion the present proposed Standard Specifications practically ignored proper provision for expansion and contraction. This is one of the most important precautions in successful sidewalk construction and one to be thoroughly and carefully provided for in the specifications. A great many men do not realize the importance of this, and there are more sidewalks ruined due to negligence or carelessness, in this respect, on the part of workmen than from any other cause.

In the early history of cement sidewalk construction, there was little attention paid to expansion and contraction. Sidewalks were laid in continuous sheets, the larger the better. The results were far from satisfactory and the blame was laid on the material instead of on the method of handling the same. By slow degrees it was discovered that better results were obtained by dividing walks, at intervals, into blocks or slabs. These divisions were not cut clear through to the bottom of the work, but from ½ to 1 in. deep, the thought being that the walk would crack anyway and the cut being the weakest part, the crack would occur there and it would not show. This, of course, was an improvement, but the cracks did not always occur where they were expected.

At the present time it is agreed that there is a certain amount of expansion and contraction in concrete and that some measures must be taken to provide for this to insure good re-

sults; particularly so in sidewalk construction, owing to its conspicuous nature. There are employed at the present various methods to accomplish this purpose, and I will endeavor to analyze some of them. Mr. Zeiser.

One is the sand joint. This is made by cutting through the base to the bottom, on a line with the proposed expansion joint, with an axe or a tool especially made for the purpose. This cut is then filled with sand and a top dressing spread over it, which is cut through to the sand. This is not a very reliable method and has a great many objectionable features. In the first place the driving of the axe or whatever tool is used down through the concrete after same has been placed, tamped and is partially set, is bad as it has a tendency to shatter and thus weaken the edges of the slabs. It is also impossible to make this cut less than from ½ to 1 in. wide at the top. The cut through the top dressing down to the sand is bound to be much narrower than the sanded cut. It will consequently leave an overhanging lip of top dressing with nothing under it but sand, making a very weak point which is liable to split off in time. There is also danger of a careless workman leaving more or less sand on the concrete at the edges of the cut, in filling the same, which will make a joint between the concrete and top dressing, leaving this point still weaker. Again there is also the danger of workmen not always making the cut through the top dressing directly over the cut in the concrete, which will cause trouble.

The specifications adopted by the Association in 1908 provide for slabs to be divided clear through at intervals of not more than 6 ft. They also provide for butting the slabs tight up against each other and then allowing not less than ½ in. to every 50 lin. ft. in one joint for expansion, which was to be filled up after the walk had set.

Now there is also some objection to this method. First, in constructing the work in a continuous operation, the first slab has very little time, if any, before the next one is laid against it and there is nothing to prevent tamping the walls of the first slab in doing this, so that they will bind. So in the case of any adjustment of foundation, instead of each slab having only its own weight to carry, it is liable to have the weight of two or

Mr. Zeiser. three slabs hanging to it, and then something is going to break. Again, if we have a cross joint every 6 ft., where is the philosophy in building 50 ft. before we provide for expansion, and then make the joint so large that we have to fill it up again. If we were going to build a railroad we would not butt the rails tight together for a half mile or so and then make an allowance for expansion, counting on transmitting all the expansion to this point. We would make proper provision at every joint. Why not apply the same principles to sidewalk construction?

Another method is to work in a continuous operation, making every joint an expansion joint and making them small enough so as not to be conspicuous, leaving a joint of not less than ⅛ in. nor more than ¼ in. wide, cut clear through to the bottom of the concrete, with the walls even and true. This is done by using metal parting strips of proper length and width. They are left in place until the top dressing is ready to finish off, when they are withdrawn, and a jointing tool is run through the space that is left, thus making a neat job. By doing this, it is absolutely certain that every slab is entirely loose and independent, having only its own weight to carry, plenty of room for expansion, and no danger of breaking.

DISCUSSION ON CONCRETE ROADS.

MR. E. V. N. HEERMANCE.—Last October, I visited the city of Gary, Ind., for the express purpose of inspecting the various kinds of concrete work which had been done at that place during the last two years. Gary is the town which has been built by the United States Steel Corporation to furnish an up-to-date dwelling place for its thousands of employees in the new $25,000,000 steel plant directly adjoining the town. Mr. Heermance.

Concrete has apparently been used in every manner known to the present state of the art, but the concrete roadway was to me very interesting and instructive. The main street, which is 200 ft. wide, is over a mile in length from the gateway of the steel plant southward, and can be extended practically indefinitely. A double line of trolley tracks, with center pole construction, runs through the middle of this thoroughfare, and the electric lights used for street illumination are erected on top of the poles. The sidewalks from building line to curb are 20 ft. in width, and excellent specimens of concrete pavement.

The roadway extends from said curb to the line of trolley tracks. This roadway was constructed of concrete 5½ ins. thick with a top dressing 1½ ins. thick, making a total of 7 ins. The concrete was composed of one part Portland cement, 3 parts sand, and 4 parts crushed stone. The greatest care was used in the selection of the aggregate. The materials were mixed by machinery, and the concrete was thoroughly and uniformly tamped at all points. Expansion joints were laid every 50 ft. from curb to side of trolley tracks, and also parallel with the curb. The top finish was blocked off 4½ x 9 ins., and the effect was that of first-class paving blocks.

I studied the roadway very carefully where it had been in use the longest, and the wear on it was barely perceptible.

MR. W. F. WISELOGEL.—I have had no experience with concrete roads, but have built alleys with just one kind of mortar, mixed 1-2-3. This was placed 8 ins. thick and simply left under Mr. Wiselogel.

Mr. Wiselogel. a float. No grooves were cut, but an expansion joint 1 in. wide was left every 50 ft., which was filled with tar, pitch or asphalt. No top coat was put on and the roadway has worn very well.

Mr. Anderson. MR. W. P. ANDERSON.—The only experience I have had in concrete roads is in driveways over reinforced concrete. The thing I want to speak about is the consistency of the wearing surface. It seems to me that a 1-2-3 mixture is a little weak for a wearing surface. If you put a 1-2 mixture on sidewalks, I should think there ought to be as strong a wearing surface for a street as for a sidewalk.

Mr. Schouler. MR. W. W. SCHOULER.—I have always understood that the coarse aggregates do not weaken the concrete to any appreciable amount. The cement and sand fill the voids of the coarse aggregates.

We eliminate expansion joints at right angles to the curb, expecting the road to crack at certain points periodically, perhaps every 40 ft. A board is placed on top of the concrete base next to the curb, an inch thick and as high as the wearing surface, to be taken out at completion of the work and filled with No. 4 paving pitch. I think this is quite necessary, especially next to the curb. A simple crack will not have the same tendency to wear hollow as a joint. The No. 4 pitch responds readily to the changes in temperature, becomes soft in summertime and slides and runs to the gutter and works out. It has occurred to me that a simple contraction joint would not damage the pavement as much as a joint large enough for pitch.

Mr. Porter. MR. H. F. PORTER.—I think it is perfectly safe to use a mixture as low as 1-2-4 in a pavement, provided it is placed wet and is well compacted. Such a mixture when tamped, which action brings the mortar to the surface, has practically a 1-2 surface. Why do we use 1 or 2 ins. of top coat? Chiefly because it is not usually expedient to lay the surface at the same time as the base and have it smooth and level. Therefore, the two operations have become separated. If it be practical to do both at once, then there is no valid reason why not as good if not a better wearing surface can be given the concrete mixture direct. This has been done successfully in a number of instances and there is no reason why it should not succeed in road construction.

REPORT OF THE COMMITTEE ON INSURANCE, LAWS AND ORDINANCES.

By W. H. Ham, Chairman.

The Committee has divided its work in two parts, one pertaining to the question of the rates of insurance on concrete and cement block structures and the other to Standard Building Regulations for Reinforced Concrete Construction.

Part I—Insurance.*

Your Committee has given a great deal of time and careful study to the question of insurance rates and the report herein presented is preliminary in its character, since the work which the Committee has undertaken is not complete and probably will not be for some little time.

After careful consideration, it appeared to the Committee that it would be highly desirable to collect for the information of the members of this Association reports of insurance on various types of buildings in which reinforced concrete was used largely in their construction. The object of this was to acquaint the members of the rates that were to be obtained on various classes of buildings, thus enabling them, through this knowledge to secure proper rates of insurance for their particular type of building. For this reason a circular letter and information blank were sent out to as many owners of concrete buildings as could be obtained (approximately 700), with a request that they fill in the blank and return to the Association at the earliest possible moment; to this request, approximately 150 replies were received, the object being to collate the information thus obtained and publish it in its collated form, the individual contributors being assured that the information obtained would not be published, but would be held as confidential.

For the convenience of reference, the various types of buildings have been classified as will be seen in Table I. The ordinates

*Discussion on Insurance, p. 450.

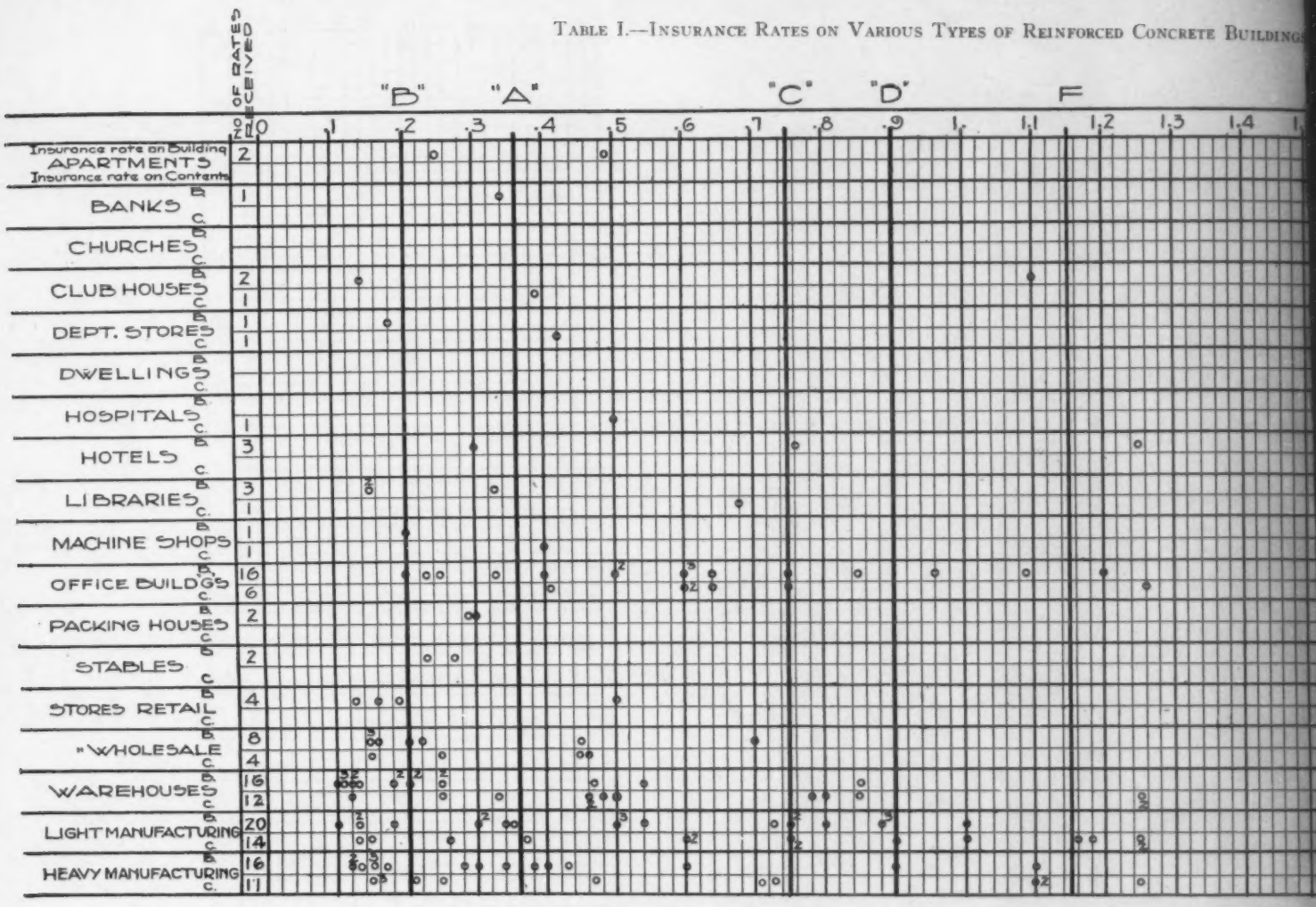
of this table are the rates of insurance per $100 and run from 0 to $4.00. There are in many cases two rates for each type of building—the upper rate being for the building and the lower rate for the contents. It is fully realized that so many conditions affect rates of insurance that it would be impossible to set an accurate average rate for each type of building, for the reason that rates of insurance on buildings are generally dependent

First, on the height and area of the building.
Second, on the surroundings.
Third, on the character of protection of exposed openings.
Fourth, on the facilities for fighting a fire.
Fifth, on the contents.

The Annual Report of the National Board of Fire Underwriters for the Year 1907, shows that the average rate of insurance for the year on all classes of buildings amounts to $1.15. The average rate of insurance on various types of construction, is placed on the diagram for the purpose of comparison. The average rate on the concrete buildings is less than four-tenths of one per cent. All except two buildings have rates less than the average rate given by the Fire Underwriters for all classes of buildings for the year 1907. Of these rates you will note from the explanation given in Table I, that one was for a building in San Francisco, a city which is composed largely of frame structures, while the other is for a frame building partly replaced by reinforced concrete having a $4.00 rate on the frame portion. Your attention is also directed to the fact that some owners find it inexpedient to carry insurance of any kind. One company in particular, who could only obtain a very excessive rate of insurance on the contents of their building, found it desirable to carry their own insurance since the annual premiums they would have to pay on the contents, capitalized, would in time afford them protection from possible fire; they did not deem it necessary to insure the building itself.

Many of the rates on buildings quoted are unnecessarily high, the rates being influenced by the character of the surroundings. For example, one of the rates cited was for a building in

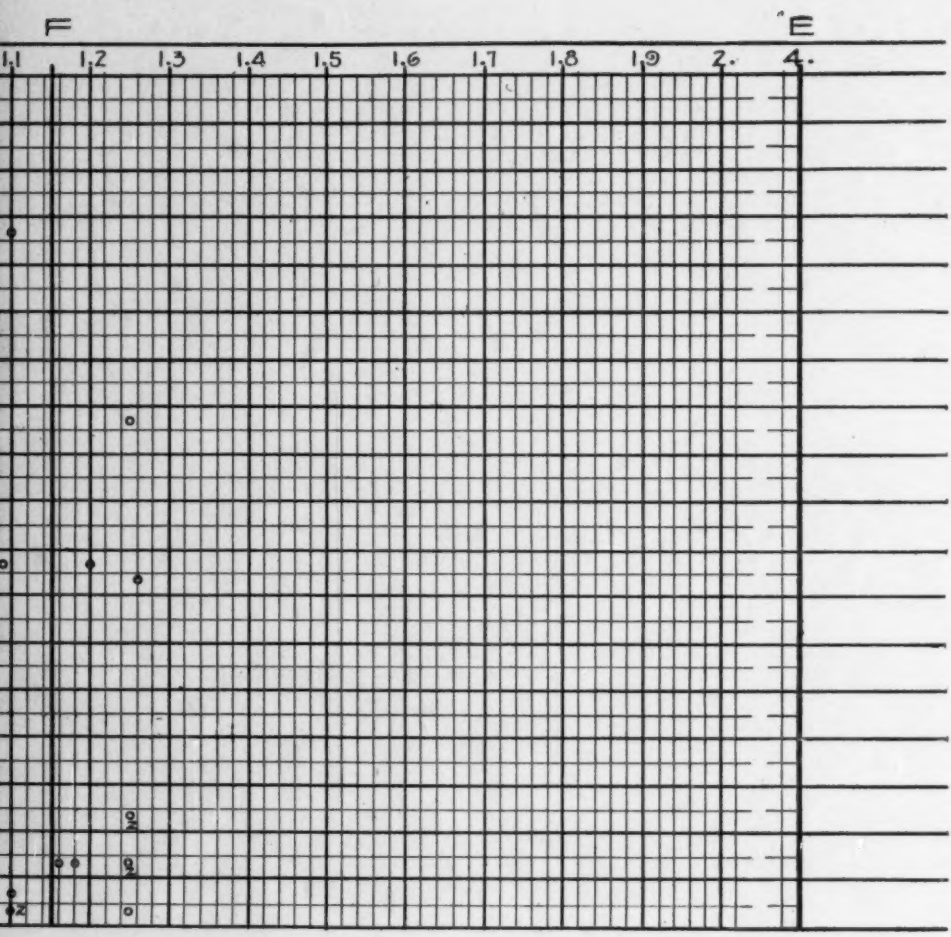
TABLE I.—INSURANCE RATES ON VARIOUS TYPES OF REINFORCED CONCRETE BUILDINGS



NOTE.—The office building given in above table having an insurance rate of $1.20 per $100 is due to it being located in a fire hazard
The hotel building with an insurance rate of $1.25 is due to the fact of its joining a wood constructed portion.

KEYNOTE—"A"—Average rate of insurance, on concrete buildings .....
"B"— " " " " " steel fire-proofed buildings.....
"C"— " " " " " slow burning mill construction.....
"D"— " " " " " buildings of joist construction.....
"E"— " " " " " buildings constructed entirely of wood ..... 4.
"F"—Average rate of insurance on all classes of buildings..... 1.

Ordinates represent the actual insurance rate on reinforced concrete buildings in fraction



it being located in a fire hazard district in San Francisco.
constructed portion.

.....	.36
uildings.....	.20
construction.....	.75
construction.....	.90
ed entirely of wood	4.00
gs.....	1.15

ed concrete buildings in fractions of per cent.

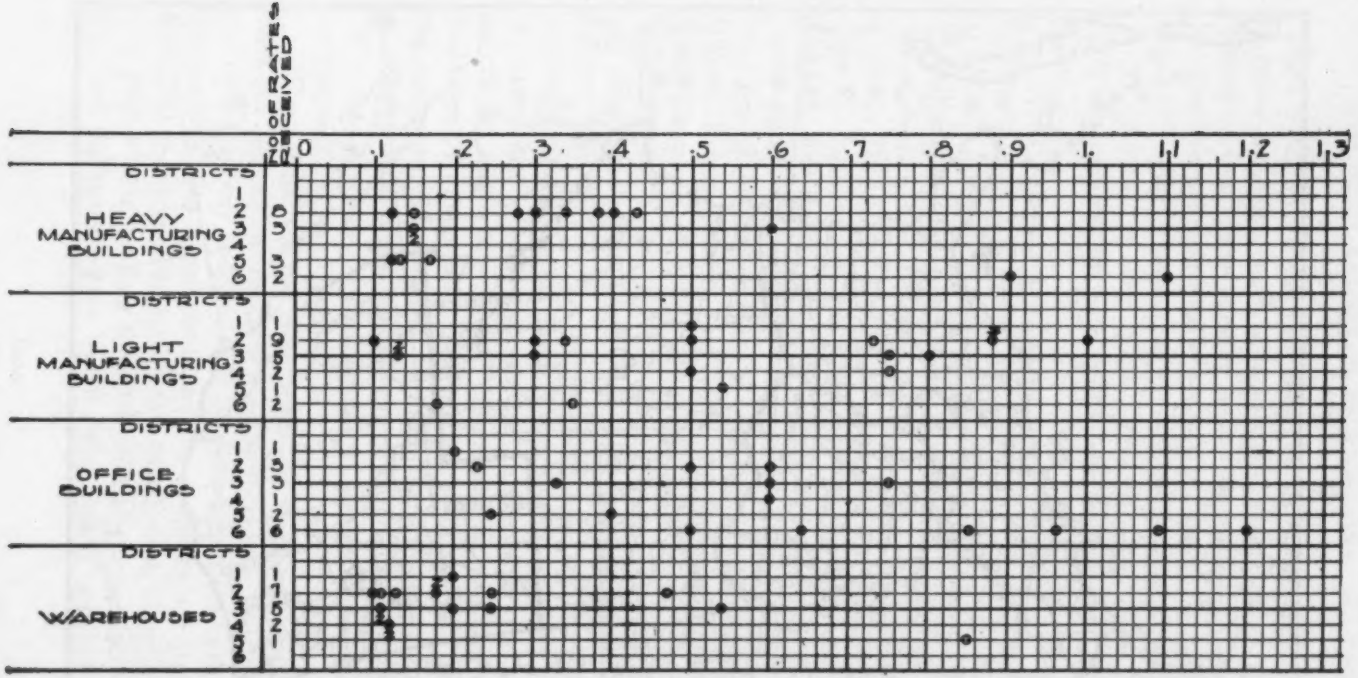


TABLE II.—SHOWING INSURANCE RATES ON FOUR CLASSES OF REINFORCED CONCRETE BUILDINGS IN THE SIX INSURANCE DISTRICTS OF THE UNITED STATES.

TABLE III.—SHOWING INSURANCE DISTRICTS ARBITRARILY FIXED BY THE COMMITTEE.

which a reinforced concrete structure had replaced a portion of a frame building, which carried an original rate of $4.00. By reason of this frame building adjoining the reinforced concrete structure without a fire-wall between, the rate on which remained the same—namely $4.00—the insurance company would only issue a rate of $1.25, whereas if the entire structure had been of reinforced concrete, the rate would have been considerably under $1.00.

The Committee has also been impressed by the fact that rates of insurance differ in different parts of the country, and in order to facilitate the study of insurance rates they have deemed it desirable to divide the country into certain insurance districts. These districts have been arbitrarily fixed by the Committee, and in Table III will be found the names of the various insurance bureaus included in each district. These districts seem to logically follow the replies to letters addressed to the various rate-making organizations. Inasmuch as rates were received on a few of the various types of buildings in all the districts only, Table II was prepared to show the comparative rates for these classes of buildings in various parts of the country. By referring to Table I, the relative rates of insurance for different types of buildings all over the country can be seen, and in this way, indirectly, the possible rates on other types of buildings for the various districts not covered can be obtained. It is interesting to note that the requirements of the insurance companies are less stringent for reinforced concrete than for buildings of inflammable construction when the fire extinguishing equipment is considered, for instance the number of sprinklers in a first-class concrete building can be reduced from that required for other classes, as also the quantity of water required for sprinkler purposes can be reduced.

The Committee has only begun its work and would appreciate any suggestions that will aid it in its work. It is hoped that the data this way collected will be of immeasurable value to the members of this Association, and the members are particularly requested to communicate with the Association, Harrison Building, Philadelphia, sending them the names of any concrete building, and the name of the owner, which they know of in their

city, so that, if letters have not already been addressed to the owner, a letter may be sent in order to secure the rate of insurance on these buildings. In this way the record can be made complete.

EXPLANATION OF TABLES.

TABLE I.

In Table I, the rate opposite the letter "B" of each class of building is the rate on the building; that opposite "C" on the contents. In many instances only one rate was obtained.

TABLE II.

Heavy Manufacturing Buildings:

From this table it will be seen that the minimum rate on heavy manufacturing buildings is .12 per cent., being in Districts Nos. 2 and 5, the maximum being 1.1 per cent. in District No. 6. The average is .357 per cent.

Light Manufacturing Buildings:

The minimum rate on this class of buildings is .1 per cent., being in District No. 2; the maximum is 1 per cent. in the same district. The average is .525 per cent.

Office Buildings:

The minimum rate on this class of buildings is .2 per cent., being in District No. 1; the maximum is 1.2, being in District No. 6. The average is .54 per cent.

Warehouses:

The minimum rate on this class of buildings is .1 per cent., being in District No. 2; the maximum is .85 per cent in District No. 5. The average is .245 per cent.

TABLE III.

Map of the United States, indicating districts covered by the several rate-making boards.

District No. 1:

Boston Board of Fire Underwriters, 55 Kilby St., Boston, Mass.
Insurance Association of Providence, Wilcox Bldg., Providence, R. I.
New Hampshire Board of Fire Underwriters, Concord, N. H.
State Associated Mill Mutuals, 31 Milk St., Boston, Mass.

District No. 2:

Underwriters' Association of New York State, Onandaga County Savings Bank Building, Syracuse, N. Y.
New York Fire Insurance Exchange, 32 Nassau St., New York, N. Y.
New York Board of Fire Underwriters, 32 Nassau St., New York, N. Y.
Suburban Fire Insurance Exchange, 32 Nassau St., New York, N. Y.
Buffalo Association of Fire Underwriters, 97 Dun Bldg., Buffalo, N. Y.
Underwriters' Association of the Middle Department, 316 Walnut St., Philadelphia, Pa.
Philadelphia Fire Underwriters' Association, 135 S. 4th St., Philadelphia, Pa.
Philadelphia Suburban Underwriters' Association, 331 Walnut St., Philadelphia, Pa.
Board of Fire Underwriters of Allegheny County, Commonwealth Building, Pittsburg, Pa.
Association of Fire Underwriters of Baltimore City, 8 and 10 South Street, Baltimore, Md.

District No. 3:

Board of Underwriters of Chicago, 159 LaSalle St., Chicago, Ill.
Milwaukee Board of Fire Underwriters, Mitchell Bldg., Milwaukee.
The Union, 125 Monroe St., Chicago, Ill.

District No. 4:

Southeastern Underwriters' Association, Equitable Bldg., Atlanta, Ga.
Louisiana Fire Prevention Bureau, Hibernia Bldg., New Orleans, La.

District No. 5:

Texas Fire Prevention Association, Wilson Building, Dallas, Tex.

District No. 6:

Board of Fire Underwriters of the Pacific, Merchants' Exchange Bldg., San Francisco, Cal.

AVERAGES.

The averages on the several classes of buildings, irrespective of districts, are as follows:

Apartments	.37	Machine Shops	.20
Banks	.34	Office Buildings	.54
Churches	..	Packing Houses	.295
Club Houses	.62	Stables	.25
Department Stores	.18	Stores, Retail	.245
Dwellings	..	Stores, Wholesale	.265
Hospitals	..	Warehouses	.245
Hotels	.77	Light Manufacturing	.525
Libraries	.21	Heavy Manufacturing	.357

PART II—SUGGESTED STANDARD BUILDING REGULATIONS FOR THE USE OF REINFORCED CONCRETE.*

Definition of Reinforced Concrete.

The term "Reinforced Concrete" shall be understood to mean an approved concrete which has been reinforced by metal in some form, so as to develop the compressive strength of the concrete.

Class of Buildings.

Reinforced concrete may be used for all classes of buildings if the design is in accordance with good engineering practice and stresses are figured as indicated in these regulations:

Plans.

Before permission is granted by the Building Department to erect any reinforced concrete building, complete plans, accompanied by specifications, static computations and descriptions showing the general arrangement and all details, signed by the engineer and architect, must be filed with the Building Department and remain on file for public inspection until the building is completed.

The static computations shall give the loads assumed separately, such as dead and live loads, wind and impact, if any, and the resulting stresses.

The specifications shall state the qualities of the materials to be used for making the concrete, and the proportions in which they are to be mixed.

Upon the completion of the building the engineer and architect shall issue, under the approval of the Building Department, signed certificates, to be posted on each floor of the building, stating the safe carrying capacity per square foot.

MATERIALS.

Cement.

Only Portland cement shall be used in reinforced concrete structures.

Quality of Cement.

Portland cement shall meet the requirements of the Standard Specifications for Cement of the American Society for Testing Materials, adopted August 15, 1908.

(See Standard No. 1 of the National Association of Cement Users.)

Tests of cement used in building operations shall be made from time to time under the supervision of the Building Depart-

* These Regulations were revised at the Convention as given on pp. 438-449.—ED.

ment in accordance with the preceding specifications. No brand of cement, which has not met these requirements, shall be used.

AGGREGATES.

Extreme care shall be exercised in selecting the aggregate for mortar and concrete, and careful tests must be made, where any doubt exists, of the materials for the purpose of determining their qualities and the grading necessary to secure maximum density or a minimum percentage of voids.

Fine Aggregate. Size.

The fine aggregate shall consist of sand, crushed stone or gravel screenings, passing when dry a screen having one-quarter inch diameter holes, and not more than 6 per cent. passing a sieve having 100 meshes per lineal inch.

It shall be of clean, silicious material free from vegetable loam or other deleterious matter.

Coarse Aggregate.

The coarse aggregate shall consist of inert material such as crushed stone, or gravel, which is retained on a screen having one-quarter inch diameter holes, the particles shall be clean, hard, durable, and free from all deleterious material. The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not prevent the concrete fully surrounding the reinforcement or filling all parts of the forms.

The maximum size for reinforced concrete work shall be such that all the aggregate shall pass a one-inch diameter ring.

Cinder concrete shall not be used for reinforced concrete structures; it may be used for fireproofing.

Where cinders are used as the coarse aggregate they shall be composed of hard, clean, vitreous clinker, free from sulphides, unburned coal or ashes.

Metal Reinforcement.

All reinforcement for concrete shall conform to the requirements of the specifications adopted by the American Railway Engineering and Maintenance of Way Association in March, 1906, for Structural Steel.

Where wire or rods up to ¼ in. diameter are used for reinforcement of slabs or for the prevention of shrinkage cracks, either material manufactured from the Bessemer billet (not re-rolled rails) or drawn from basic open hearth steel may be used. The working stress allowed, however, shall not exceed units given in these regulations, viz., 16,000 lbs. in tension

Mixing. The ingredients of concrete shall be thoroughly mixed to the desired consistency, and the mixing shall continue until the cement is uniformly distributed and the mass is uniform in color and homogeneous.

Measuring Proportions. Methods of measurement of the proportions of the various ingredients, including the water, shall be used, which will secure separate uniform measurements at all times.

Machine Mixing. When the conditions will permit, a machine mixer of a type which insures the proper proportioning of the materials throughout the mass shall be used.

Hand Mixing. When it is necessary to mix by hand, the mixing shall be on a water-tight platform, and special precautions must be taken to turn the materials until they are homogeneous in appearance and color.

Consistency. The materials must be mixed wet enough to produce a concrete of such a consistency as will flow into the forms and about the metal reinforcement, and which, on the other hand, can be conveyed from the mixer to the forms without separation of the coarse aggregate from the mortar.

Retempering. Retempering mortar or concrete, *i. e.*, remixing with water after it has partially set, shall not be permitted.

Placing of Concrete. Methods. Concrete after the addition of water to the mix shall be handled rapidly, and in as small masses as is practicable, from the place of mixing to the place of final deposit, and under no circumstances shall concrete be used that has partially set before final placing.

The concrete shall be deposited in such a manner as will permit the most thorough compacting, such as can be obtained by working with a straight shovel or slicing tool kept moving up and down until all the ingredients have settled in their proper place by gravity and the surplus water forced to the surface.

Before placing the concrete care shall be taken to see that the forms are substantial and thoroughly wetted and the space to be occupied by the concrete free from debris. When the placing of the concrete is suspended, all necessary grooves for joining future work shall be made before the concrete has had time to set.

When work is resumed, concrete previously placed shall be roughened, thoroughly cleansed of foreign material and laitance, drenched and slushed with a mortar consisting of one part Portland cement and not more than two parts fine aggregate.

The faces of concrete exposed to premature drying shall be kept wet for a period of at least seven days.

Freezing Weather. Concrete shall not be mixed or deposited at a freezing temperature, unless special precautions are taken to avoid the use of materials containing frost or covered with ice crystals, and to provide means to prevent the concrete from freezing after being placed in position and until it has thoroughly hardened.

Placing of Reinforcement. The reinforcement shall be accurately located in the forms and secured against displacement.

JOINTS.

Reinforcement. Wherever it is necessary to splice reinforcement, that is, in tension, by means of lapping, the length of the lap shall be determined upon the basis of the safe bond stress and the stress in the bar at the point of splice; or a connection shall be made between the bars of sufficient strength to carry the stress. Splices at the point of maximum stress must be avoided.

In columns large bars (bars whose areas exceed 1¼ in. round) shall be properly butted and spliced. Smaller bars than above may be treated as indicated for tension reinforcement.

Concrete. (*a*) Reinforced concrete work shall be stopped at such points that the joints will have the least possible effect on the strength of the structure. Footings shall be cast at one operation.

Columns. (*b*) Work in columns shall be stopped at the underside of the lowest beam or girder bearing on the column.

Beams and Girders. (*c*) Joints in beams and girders shall be vertical and within the middle third of the span. Any concrete which may run past the bulkheads must be cleaned up before the concreting of the next section is started.

Where brackets are used, the bracket shall be considered as a part of the beam or girder.

Slabs. (*d*) Joints in slabs shall be near the center of the span. No joint will be allowed between slab and beam or girder.

Fireproofing. Reinforcement in columns and girders shall be protected by a minimum of two inches of concrete. Reinforcement in beams by one and one-half inches and floor slabs by one inch.

GENERAL ASSUMPTIONS.

Dead Loads. The dead load shall include the weight of the structure and all fixed loads and forces.

Live Loads. The live load shall include all loads and forces which are variable.

Factors of Safety and Reduction of Loads. A factor of safety of four shall be used for the live and the dead loads. The minimum live load on any floor shall be 50 pounds per square foot. Minimum live load on roofs shall be 30 pounds per square foot.

The weight of the reinforced concrete shall be taken as 150 pounds per cubic foot.

No reduction of loads shall be allowed for figuring floor slabs.

No reduction of loads shall be allowed for figuring beams.

A reduction of 15 per cent. live load shall be allowed in figuring the girders, except in buildings used for storage purposes.

The roof shall be figured to carry 30 pounds live load per square foot unless otherwise noted.

A reduction of live load coming to the column supporting the floor below the roof of 5 per cent. to be allowed and further reduction of 5 per cent. of the live load of each story below until the total reduction shall amount to 50 per cent. of the live load of any floor, after which all loads shall be figured net to the foundations, but no live load less than 50 pounds per square foot, including reduction, shall be allowed.

In assuming the load coming to the columns all beams and girders shall be considered as carrying a net load consisting of 100 per cent. each of the live and dead load, subject to the above reductions.

Length of Beams and Columns. The span length for beams and slabs shall be taken as the distance from center to center of supports, but shall not be taken to exceed the clear span plus the depth of beam or slab. Brackets shall not be considered as reducing the clear span.

Length of column shall be taken as the maximum unsupported length.

Where slabs and beams are figured as simple beams the length shall be considered as the clear distance between supports excluding brackets.

Internal Stresses.

As a basis for calculations for the strength of reinforced concrete construction, the following assumptions shall be made:

1. A plane section before bending remains plane after bending.

2. The modulus of elasticity of concrete in compression within the usual limits of working stresses is constant.

3. In calculating the moment of resistance of beams the tensile stresses in the concrete shall be neglected.

4. Perfect adhesion is assumed between concrete and reinforcement. Under compressive stresses the two materials are therefore stresses in proportion to their moduli of elasticity and their distance from the neutral axis.

5. The ratio of the modulus of elasticity of steel to the modulus of elasticity of concrete shall be assumed to be 15.

6. Initial stress in the reinforcement due to contraction or expansion in the concrete may be neglected.

Ratio of Least Diameter to Height.

The ratio of least diameter to height shall be taken as one-fifteenth.

Greater ratios shall be reduced by satisfactory column formulæ.

BENDING MOMENTS.

Slabs Reinforced in One Direction.

The bending moment of slabs supported at two sides only shall be 1/8 W. L.

Bending Moment, Continuous Slabs.

For interior slabs overhanging two or more supports the bending moment shall be 1/12 W. L. The reinforcement at the top of the slab over supports must equal half that used at the center.

Bending Moment for Slabs Supported on all Four Sides and Reinforced in Two Directions.

Slabs that are supported on four sides and reinforced in both directions and having half of each line of reinforcement raised to the top of the slab over supports and passing into the adjoining slabs on at least three sides may be figured on the basis of bending moments equivalent to 1/12 W. L. for load in each direction, the distribution of the loads to be determined by the formula:

$$r = \frac{b^4}{L^4 + b^4}$$

in which r equals proportion of load carried by the transverse reinforcement, L equals length, and b equals breadth of slab.

If the length of the slab exceeds 1.5 times its width the entire load shall be carried by transverse reinforcement. Slabs whose length is 1.5 times its width or less, shall be reinforced in both directions.

Where the slabs are not continuous over the beams on at least three sides as in the corners of a building unless diagonal beams are used at the corner, the bending moment shall not be figured less than 1/16 W. L. or 1/8 W. L. in each direction.

Bending Moment Simple Beams.

The bending moment of beams supported at the ends only shall be figured 1/8 W. L. where "W" equals the total load and "L" equals the clear span. Beams supported at one end and continuous at the other to be figured partially restrained with a center bending moment of 1/10 W. L.

Beams supporting rectangular slabs reinforced in both directions shall be figured to have a bending moment varying as the ordinates of the two triangles whose common base is the beam length and sides formed by the diagonals of the panels.

Bending Moment Continuous Beams

When beams or girders are continuous over two or more supports, the interior beams may be considered as partially restrained, and the bending moments at the center and support figured 1/12 W. L. unless the concrete at the bottom of the beam at the support shall by this consideration receive excess compression.

Slabs Forming Tee Beams.

In beam and slab construction, an effective metallic bond should be provided at the junction of the beam and slab. When the principal slab reinforcement is parallel to the beam, transverse reinforcement should be used extending over the beam and well into the slab.

Where adequate bond between slab and web of beam is provided, the slab may be considered as an integral part of the beam, but its effective width, *i. e.*, its overhanging width on either side of the web, shall not exceed six times the thickness of the slab.

In the design of tee beams acting as continuous beams, due consideration should be given to the compressive stresses at the support on the bottom of the beam.

WORKING STRESSES.

Concrete composed of materials meeting the requirements of these regulations, mixed in proportion of one part of cement

and six parts of aggregate (fine and coarse), shall develop a compressive strength of 2,000 pounds per square inch in 28 days when tested in 8 ins. in diameter cylinders 16 ins. long under laboratory conditions of manufacture and storage, using the same consistency as is used in the field. When the proportion of cement is increased, using the best quality of aggregates, an increase may be made in all working stresses proportional to the increase in compressive strength at 28 days, but this increase shall not exceed 25 per cent. On this basis the following working stresses shall be allowed in construction:

Bearing compression, 650 pounds per square inch.

Bearing Compression Extreme Fiber.

Compression in extreme fiber, 650 pounds per square inch. With increase of 15 per cent., near supports in continuous beams.

Tension.

No allowance shall be made for tension in concrete.

Axial Compression as in Columns with Vertical Reinforcement only.

Axial compression in columns without hoops, 450 pounds per square inch.

Columns with One Per Cent. of Hoops.

Axial compression in columns with 1 per cent. of hooping, 540 pounds per square inch.

Columns with One Per Cent. of Hoops and 1 to 4 Per Cent. of Vertical Reinforcement.

Axial compression in columns with 1 per cent. hooping and 1 to 4 per cent. of vertical reinforcement, 650 pounds per square inch on the concrete and 9,750 on the vertical steel. (See hooped columns.)

Columns Reinforced with Structural Steel which Thoroughly Incases the Concrete Core.

Columns reinforced with structural steel thoroughly encased in concrete, 650 pounds per square inch on the concrete and 9,750 pounds per square inch on the structural steel.

Shear in Concrete.

Shear in concrete, 75 pounds per square inch.

Diagonal Tension in Concrete.

Diagonal tension in concrete, 75 pounds per square inch.

Bond of Concrete.

Bond of concrete, 75 pounds per square inch.

Ratio of Moduli of Elasticity.

The ratio of modulus of elasticity of concrete to steel shall be considered as one to fifteen.

Stresses in the Steel Reinforcement. Tensile Stress.

The allowable tensile stress in steel reinforcement to be 16,000 pounds per square inch.

Compressive Stress.

The compressive stress in the steel reinforcement to be fifteen times the allowed compression in concrete in which the steel is embedded.

Removal of the Forms.

Under no consideration shall forms be removed until the concrete has hardened sufficiently to permit their removal with safety. Forms shall not be removed from floor slabs in less than seven days.

Sides of beams may be removed at the same time as the floor slabs provided original supports under beams and girders are left in place.

Removal of Forms from Columns.

Where original supports remain under beams and girders coming to the columns, the forms shall not be removed from the columns in less than four days.

Removal of Supports from Beams and Girders.

The original supports for all beams and girders must remain in place at least ten days, but all beams and girders having more than thirty feet span from center to center of support shall be considered as special cases and shall be subject to inspection of the Building Department before removal of supports.

Reinforced Concrete Walls.

Reinforced concrete walls may be used in place of brick or stone walls. The thickness required shall be two-thirds of that required for brick walls, as shown by the Building Department Regulations.

Concrete walls must be reinforced in both directions. The maximum spacing of reinforcing bars shall be 18 in. centers, reinforcement in either or both faces of the wall being considered.

Reinforcement shall be not less than one-fourth of 1 per cent.

Height of Buildings of Reinforced Concrete.

There shall be no limit upon the height of buildings of reinforced concrete except as limited by the requirements in these regulations.

Records.

There must be kept an exact record of the progress of each operation where the same can be inspected by the Building Department. These records shall show the date of placing of all the concrete and date of removal of the forms and must be kept and turned over to the Building Department when the building is completed.

Tile and Joist Construction.

Wherever floor constructions are built with a combination of tile or other fillers between joists, the following rules regarding the dimensions and methods of calculations of construction shall be observed.

Relation of Depth of Joist to Length.

Ratio of minimum depth to clear span of joist shall not be greater than one to eighteen.

Wherever a portion of the slab above the tile joist shall be

considered as acting as a "T" beam section, the slab portion must be cast monolithic with the joist and must have a minimum thickness of at least 2 ins. on all spans. Otherwise, all regulations applying to "T" beams shall apply to tile and joist construction.

Where the joists are figured as rectangular beams, in accordance with the standard regulations of this type of beams, the slab shall be considered as independent of the structural part of the building.

Wherever porous tiles, or other material which by its nature will absorb water from the concrete, are used between the joists, care must be taken to thoroughly saturate the tiles, or other material, with water immediately before the concrete is placed.

Reinforcement for slabs over joists construction below 20 in. centers need not be closer than 24 ins. in each direction.

Respectfully submitted,

W. H. HAM, *Chairman;*
EDWARD D. BOYER,
H. S. DOYLE,
EMILE G. PERROT.

MINORITY REPORT.

The undersigned has declined to sign the majority report with its suggested Standard Building Regulations for the Use of Reinforced Concrete, the reason being that he did not have an opportunity to confer with other members of the Committee in the preparation of this Standard, and does not agree with several of its provisions, having particular reference to the question of fire resistance. Two features seem to warrant special mention, viz.:

Thickness of Walls.—Paragraph 9 specifies that reinforced concrete walls of a reduced thickness may be used in place of brick or stone, no idea being given as to what reduction should be allowed, but implying that any wall, whether constituting an outside wall or fire division—provided it is regarded as a curtain

wall or not bearing any appreciable load—may be 4 ins. Such a provision could by no means be considered adequate to cover the walls of a fire-proof building.

Fireproofing.—All reference to fireproofing is left to one item (p. 411) and attempts to express in three short lines all that is needed in the matter of insulation of steel members for all classes and conditions of buildings. No tests have ever been made, nor have any fires occurred of which the writer is aware showing that 2 ins. of concrete is sufficient protection for reinforcement of columns. I do not believe it wise to estimate that thickness as sufficient protection for such vital members as columns, particularly in large mercantile buildings containing quantities of combustible material which would provide a long and hot fire. I have not yet seen any data which would warrant the acceptance of 2 ins. of protection around reinforcement of girders and beams. That thickness would doubtless be quite acceptable in some classes of buildings, but not in such as by nature of their location and occupancy would be subject to long and intense fires.

With due deference to the authority and standing of the other members of the Committee, I venture to express the opinion that this report has been made up without sufficient regard to the matter of fire resistance, notwithstanding the fact that one of the chief arguments put forth by the builders of reinforced concrete construction is that it is fireproof.

I trust, however, that these statements will not be construed as a disapproval of reinforced concrete construction, nor a disinclination to regard it as reasonably fireproof when properly designed and erected. I have seen enough tests of the material, both as experiments and under working conditions to have a very high regard for it as a fire resistant, and hope that before long a standard specification will be brought out which will greatly extend such construction under conditions satisfactory to its designers and builders, as well as to the fire insurance companies, who may be conceded to have a considerable interest in the subject.

EDWARD T. CAIRNS.

APPENDIX.

The Appendix on the following pages represent:

(*a*) Standard Specifications for Cement.
(*b*) Standard Specifications for Structural Steel.
(*c*) Tabulated Synopsis of Building Regulations in Europe.
(*d*) Tabulation of Building Code Requirements in the principal cities of the United States.

(*a*) STANDARD SPECIFICATIONS FOR CEMENT.*

ADOPTED AUGUST 15, 1908, AND REVISED JULY, 1909, BY THE AMERICAN SOCIETY FOR TESTING MATERIALS.

GENERAL OBSERVATIONS.

1. These remarks have been prepared with a view of pointing out the pertinent features of the various requirements and the precautions to be observed in the interpretation of the results of the tests.

2. The Committee would suggest that the acceptance or rejection under these specifications be based on tests made by an experienced person having the proper means for making the tests.

SPECIFIC GRAVITY.

3. Specific gravity is useful in detecting adulteration. The results of tests of specific gravity are not necessarily conclusive as an indication of the quality of a cement, but when in combination with the results of other tests may afford valuable indications.

FINENESS.

4. The sieves should be kept thoroughly dry.

*Standard No. 1. National Association of Cement Users.

TIME OF SETTING.

5. Great care should be exercised to maintain the test pieces under as uniform conditions as possible. A sudden change or wide range of temperature in the room in which the tests are made, a very dry or humid atmosphere, and other irregularities vitally affect the rate of setting.

TENSILE STRENGTH.

6. Each consumer must fix the minimum requirements for tensile strength to suit his own conditions. They shall, however, be within the limits stated.

CONSTANCY OF VOLUME.

7. The tests for constancy of volume are divided into two classes, the first normal, the second accelerated. The latter should be regarded as a precautionary test only, and not infallible. So many conditions enter into the making and interpreting of it that it should be used with extreme care.

8. In making the pats the greatest care should be exercised to avoid initial strains due to molding or to too rapid drying-out during the first twenty-four hours. The pats should be preserved under the most uniform conditions possible, and rapid changes of temperature should be avoided.

9. The failure to meet the requirements of the accelerated tests need not be sufficient cause for rejection. The cement may, however, be held for twenty-eight days, and a retest made at the end of that period, using a new sample. Failure to meet the requirements at this time should be considered sufficient cause for rejection, although in the present state of our knowledge it cannot be said that such failure necessarily indicates unsoundness, nor can the cement be considered entirely satisfactory simply because it passes the tests.

SPECIFICATIONS.

GENERAL CONDITIONS.

1. All cement shall be inspected.

2. Cement may be inspected either at the place of manufacture or on the work.

3. In order to allow ample time for inspecting and testing, the cement should be stored in a suitable weather-tight building having the floor properly blocked or raised from the ground.

4. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment.

5. Every facility shall be provided by the Contractor and a period of at least twelve days allowed for the inspection and necessary tests.

6. Cement shall be delivered in suitable packages with the brand and name of manufacturer plainly marked thereon.

7. A bag of cement shall contain 94 pounds of cement net. Each barrel of Portland cement shall contain 4 bags, and each barrel of natural cement shall contain 3 bags of the above net weight.

8. Cement failing to meet the seven-day requirements may be held awaiting the results of the twenty-eight day tests before rejection.

9. All tests shall be made in accordance with the methods proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, presented to the Society January 21, 1903, and amended January 20, 1904, and January 15, 1908, with all subsequent amendments thereto. (See addendum to these specifications.)

10. The acceptance or rejection shall be based on the following requirements:

NATURAL CEMENT.

11. *Definition.* This term shall be applied to the finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas.

FINENESS.

12. It shall leave by weight a residue of not more than 10 per cent on the No. 100, and 30 per cent on the No. 200 sieve.

TIME OF SETTING.

13. It shall not develop initial set in less than ten minutes; and shall not develop hard set in less than thirty minutes, or in more than three hours.

TENSILE STRENGTH.

14. The minimum requirements for tensile strength for briquettes one inch square in cross section shall be as follows, and shall show no retrogression in strength within the periods specified:

Age.	*Neat Cement.*	*Strength.*
24 hours in moist air		75 lbs.
7 days (1 day in moist air, 6 days in water)		150 "
28 days (1 " " " 27 " ")		250 "

One Part Cement, Three Parts Standard Sand.

7 days (1 day in moist air, 6 days in water)	50 lbs.
28 days (1 " " " 27 " ")	125 "

If the minimum strength is not specified, the mean of the above values shall be taken as the minimum strength required.

CONSTANCY OF VOLUME.

15. Pats of neat cement about three inches in diameter, one-half inch thick at the centre, and tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(*a*) A pat is then kept in air at normal temperature.

(*b*) Another is kept in water maintained as near 70 F. as practicable.

16. These pats are observed at intervals for at least 28 days, and, to satisfactorily pass the tests, should remain firm and hard and show no signs of distortion, checking, cracking or disintegrating.

PORTLAND CEMENT.

17. *Definition.* This term is applied to the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than 3 per cent. has been made subsequent to calcination.

SPECIFIC GRAVITY.

18. The specific gravity of the cement shall be not less than 3.10. Should the tests of cement as received fall below this requirement, a second test may be made upon a sample ignited at a low red heat. The loss in weight of the ignited cement shall not exceed 4 per cent.

FINENESS.

19. It shall leave by weight a residue of not more than 8 per cent. on the No. 100, and not more than 25 per cent. on the No. 200 sieve.

TIME OF SETTING.

20. It shall not develop initial set in less than thirty minutes, and must develop hard set in not less than one hour, nor more than ten hours.

TENSILE STRENGTH.

21. The minimum requirements for tensile strength for briquettes one inch square in section shall be as follows, and shall show no retrogression in strength within the period specified:

Age.	*Neat Cement.*	*Strength.*
24 hours	in moist air	175 lbs.
7 days	(1 day in moist air, 6 days in water)	500 "
28 days	(1 " " " 27 " ")	600 "

One Part Cement, Three Parts Standard Sand.

7 days	(1 day in moist air, 6 days in water)	200 lbs.
28 days	(1 " " " 27 " ")	275 "

If the minimum strength is not specified, the mean of the above values shall be taken as the minimum strength required.

CONSTANCY OF VOLUME.

22. Pats of neat cement about three inches in diameter, one-half inch thick at centre, tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(*a*) A pat is then kept in air at normal temperature and observed at intervals for at least 28 days.

(*b*) Another pat is kept in water maintained as near 70° F. as practicable, and observed at intervals for at least 28 days.

(*c*) A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel for five hours.

23. These pats, to satisfactorily pass the requirements, shall remain firm and hard and show no signs of distortion, checking, cracking, or disintegrating.

SULPHURIC ACID AND MAGNESIA.

24. The cement shall not contain more than 1.75 per cent. of anhydrous sulphuric acid (SO_3), nor more than 4 per cent. of magnesia (MgO).

(*b*) STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL.

ADOPTED MARCH, 1906, by the
AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION.

Process of Manufacture.

83. Steel shall be made by the open-hearth process.

Schedule of Requirements.

84. The chemical and physical properties shall conform to the following limits:

Elements Considered.	Structural Steel.	Rivet Steel.
Phosphorus, max... Basic	0.04 per cent.	0.04 per cent.
Phosphorus, max... Acid	0.08 "	0.04 "
Sulphur, maximum	0.05 "	0.04 "
Ultimate tensile strength.	Desired	Desired
Pounds per square inch	60,000	50,000
Elong. min. % in 8", Fig. 1.	1,500,000*	1,500,000
	Ult. tensile stre'gth	Ult. tensile stre'gth
Character of Fracture	Silky	Silky
Cold Bends without Fracture	180° flat†	180° flat‡

* See paragraph 11. † See paragraphs 12, 13 and 14. ‡ See paragraph 15.

The yield point, as indicated by the drop of beam, shall be recorded in the test reports.

Allowable Variations.

85. If the ultimate strength varies more than 4,000 lbs. from that desired, a retest shall be made on the same gage, which, to be acceptable, shall be within 5,000 lbs. of the desired ultimate.

Chemical Analyses.

86. Chemical determinations of the percentages of carbon, phosphorus, sulphur and manganese shall be made by the manufacturer from a test ingot taken at the time of the pouring of each melt of steel, and a correct copy of such analysis shall be furnished to the engineer or his inspector. Check analyses shall be made from finished material, if called for by the purchaser, in which case an excess of 25 per cent. above the required limits will be allowed.

Number of Tests.

92. At least one tensile and one bending test shall be made from each melt of steel as rolled.

Thick Material. 95. Full-sized material for steel one inch thick and over, tested as rolled, shall bend cold 180 degrees around a pin, the diameter of which is equal to twice the thickness of the bar, without fracture on the outside of bend.

Finish. 98. Finished material shall be free from injurious seams, flaws, cracks, defective edges or other defects, and have a smooth, uniform and workmanlike finish. Plates 36 ins. in width and under shall have rolled edges.

Stamping. 99. Every finished piece of steel shall have the melt number and the name of the manufacturer stamped or rolled upon it.

Defective Material. 100. Material which, subsequent to the above tests at the mills, and its acceptance there, develops weak spots, brittleness, cracks or other imperfections, or is found to have injurious defects, will be rejected at the shop and shall be replaced by the manufacturer at his own cost.

(*c.*) TABULATED SYNOPSIS.*

Representing Building Regulations in Great Britain, Germany, France, Switzerland and Austria.

*Reprinted from Concrete and Constructural Engineering, London, July, 1908.

SUBJECT	A (GREAT BRITAIN) British Reinforced Concrete Committee:—Recommendations, 1907.	B (GERMANY) Prussian Government:—Regulations, 1904.	C (FRANCE) French Government:—Rules, 1907.	D (SWITZERLAND) Swiss Society of Engineers and Architects:—Recommendations, 1903.	E (AUSTRIA) Austrian Ministry of the Interior:—Rules, 1908.
CEMENT.	To comply with requirements of specification of the British Engineering Standards Committee. Tests for constancy of volume, and setting time should be frequently made.	Must fulfil requirements of Prussian Specification. Certificates as to quality to contain statements as to constancy of volume, time of setting, fineness of grinding and tensile and compressive strength. To be delivered in the original packages.	Cement to be slow setting, except in cases where the concrete is poured into molds.	Quality to be equal to Swiss standard.	Full specification given.
SAND.	Hard grains of various sizes up to ¼ in. mesh, of which at least 75% must pass ⅛ in. mesh. Clean free from ligneous, organic, or earthy matter. Mortar of proposed sand, to be tested—washing does not always improve sand.	Only sharp sand, gravel, or other recognized material of suitable coarseness to be used.	*Nil*	To be clean and free from earthy matter.	Full specification given.
STONE.	Gravel, hard stone or other suitable material, clean and angular, to pass ¼ in. mesh, and retained on ¾ in. mesh, as a rule but maximum size to be such as will pass between reinforcing bars or between bars and centering. Sand to be separated from stone before mixing. Limestone not to be used if structure to be fire-resisting.	*Nil*	*Nil*	Gravel to be of such size as to pass between reinforcing bars, and between bars and falsework.	Full specification given.
CONCRETE.	Tests to be made in important cases. Cement to be measured by weight, 1 cu. ft. of cement weighs 90 lbs. Sufficient cement	Compressive strength of concrete after 28 days must be stated in description, *vide* "General Regulations."	Amount of water must be sufficient for ensuring fluidity necessary for perfect embedding of reinforcements, and complete	Compressive strength of concrete to be at least 2,275 lbs. per sq. in. after 28 days in damp air. Mixture to be such that	Concrete not to be weaker than 428 lbs. of cement per cu. yd. of sand and stone. Strengths of concretes of

Subject	A (Great Britain)	B (Germany)	C (France)	D (Switzerland)	E (Austria)
Concrete—(cont.)	added to sand to fill interstices. Sufficient mortar added to stone as will fill interstices + 10%. Machine mixing used where practicable. When hand mixing materials turned over until even color on clean platform. Amount of water depends on temperature and other factors. Seawater not to be used.	Cement as a rule to be measured by weight.	filling of voids in aggregate.	there is at least 505 lbs. of cement per cu. sq. yd. of concrete in position. To be mixed in suitable machines, proper proportions carefully regulated. Strength determined in Federal Laboratory on cubes 6¼ x 6¼ x 6¼ in. or prisms 14⅛ x 4¾ x 4¾ in. Prisms will also be used to ascertain resistance to tension from bending tests.	various proportions are given.
REINFORCEMENT.	Ultimate strength not less than 60,000 lbs. per sq. in. Elastic limit not less than 50% or more than 60% of ultimate strength. Elongation small round bars not less than 22% on a length of 8 diameters. Round bars over 1 in. in diameter not less than 27% on a length of 4 diameters. Other sections as prescribed in British Standard Specification. Welding in general forbidden. In special cases welds to be at points of least stress.	*Nil*	*Nil*	*Nil*	*Nil*
ERECTION.	Reinforcements to be placed and kept in proper position. Apart from fire resisting the bars to be not nearer than 1 in. from surface of beams, and ½ in. from surface of floor slabs or other thin structures. Metal to be properly coated with cement. Layers of concrete before	Reinforcement to be correctly placed. Concrete layers before ramming not to exceed 6 in. Metal to be thoroughly coated with cement mortar. Concrete to be prepared only in such quantities as required for immediate use. It is to be put in place im-	Fixing in position of reinforcement to be of sufficient rigidity to resist shocks and loads during construction. Concrete, except when poured into moulds, to be rammed in layers suitable to size of aggregate and spacing of reinforcements, but never greater than 2 in. after ramming	Reinforcements to be placed in exact positions shown on the drawings and their sizes must be carefully checked. If metal is rusty it must be cleaned before putting in place. Work of erection only to be entrusted to those thoroughly conversant with	Minimum distance of reinforcements from side of molds to be 0.4 in. Only skilled workmen and experienced foremen to be employed. Concrete of consistency of moist earth in layers not greater than 6 inches. Wet concrete in layers not exceeding 8 inches. Concrete not dropped from

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Erection—(cont.)	ramming not to exceed 3 in. Recently laid concrete should be wetted before adding fresh layer. Hardened surfaces to be hacked up, swept clean and covered with cement grout before adding new concrete. No concreting to be carried on when temperature below 34 degrees Fahr. All shaking or jarring to be avoided. Fresh work to be protected from frost and sun rays.	mediately after mixing and uniformly rammed. If plastic, ramming to be continued till water appears on surface. For ramming properly shaped stamps of appropriate weight must be used. Main walls to be raised simultaneously through their whole length, and care taken to make good connection with adjoining cross walls. Layers completing a story to be finished off level. Recently laid concrete to be wetted before more added. Hardened surfaces to be roughened, swept and wetted. In construction of walls and columns in buildings, the upper story not to be commenced until that below has been approved. Concreting not to be carried on in frost unless precautions taken. After a frost work not to be recommenced without permission of authority. Until sufficiently hardened concrete to be protected from frost, premature drying, and from shaking or overloading. Time book to be kept. Days of frost entered with records of temperature.	except when stones are used as aggregate. Reinforcements to be so spaced from each other and sides of moulds, that ramming may be perfect and the concrete be forced into contact with them. Thickness of concrete outside reinforcements never to be less than 0.6 to 0.8 in. Stopping of concreting to be avoided as much as possible, when it is necessary hardened concrete to be cleaned, roughened and watered before fresh concrete added. Concrete to be kept moist for 15 days after moulding. Work to be stopped in frosty weather unless efficaciously protected. If any part of work injured by frost it must be cut out.	this method of construction. Only trustworthy foreman having experience in this class of work to be employed.	greater height than 6 feet. Reinforcements to be carefully placed and fixed, and well covered by the mortar of the concrete. Interruption of concreting only where concrete not exerting full allowable resistance. Hardened concrete to be roughened, cleaned and wetted with 1 to 1 neat cement grout before more added. Concrete not laid in frosty weather unless precautions taken. Concrete to be kept wet until sufficiently hardened. Use of members molded in advance not allowed without special permission. Provision for protection against penetration of water.

Subject	*A (Great Britain)*	*B (Germany)*	*C (France)*	*D (Switzerland)*	*E (Austria)*
FIRE PRECAUTIONS.	No limestone to be used. Best materials for fire resistance:— (1) Coke breeze, cinders or slag. (2) Broken bricks. (3) Gravel or stone. Rigidly attached web members, loose stirrups, bent-up bars or other connection between metal and compression sides of beams or slabs are very desirable. Metal to be covered by concrete 1 in. thick for floor slabs, 1½ to 2 in. thick for other parts—all angles to be splayed or rounded. For highest fire resistance concrete should be covered with special fire resisting materials.	*Nil*	*Nil*	*Nil*	*Nil*
FALSE-WORK.	To be rigid and unyielding during laying and ramming of concrete. To be easily removed without jarring concrete. Timber to be covered with limewash.	To possess sufficient resistance to bending and shaking during ramming, and to be so arranged so as to be removable without danger to the necessary supports remaining in place. All shaking to be avoided when removing falsework.	To be of sufficient rigidity to withstand without noticeable deflection loads and shocks occurring during construction and in removal of molds, &c.	Care to be given to design and erection, so that it is capable of allowing ramming of concrete in thin layer without injury.	To be rigid and unyielding during laying and ramming concrete. To be removable without shock. Proper cambers to be provided. No appreciable loading until forms and supports are removed.
STRIKING CENTERS.	Depends on dimensions or thickness of structure, amount of water used in mixing, state of the weather during deposition and setting, and whether or not to be loaded directly after removal of centering. Casings for columns and sides of beams and bot-	Casings for columns and centering for floors of 5 ft. span or less may be removed not less than 3 days, and all other falsework not less than 14 days after molding. Special care to be taken in removal if concrete is finished shortly before commencement of a frost.	Molds, &c., to be removed without shocks by purely static forces and only after the concrete has sufficient resistance to sustain without injury the stresses to which it will be subjected.	Before striking it must be ascertained that concrete is sufficiently set. Centering for slabs or beams not exceeding 10 ft. span not to be removed in less than 10 days after molding. For beams of 10 to 20 ft. span and for columns, falsework to remain for	Supporting parts not to be removed until concrete sufficiently hardened and never before four weeks after completion of ramming, but sides of forms after four days. If frost occurs during setting of concrete, period to be extended by time of

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Striking Centers (cont.)	toms of floor slabs not more than 4 ft. span not to be removed under 8 days. Bottoms of beams or floor slabs of greater span than 4 ft. to remain up at least 14 days. For large span arches centering not to be removed under 28 days. If frost occurs during setting of concrete period to be extended by time of duration of frost.	If frost occurs during setting of concrete, above periods are to be increased by the time of duration of the frost.		20 days and for longer spans 30 days. In buildings with several floors, the removal of supports to begin on the top floor and proceed downwards. Before striking, report to be made stating if all parts of the work have been properly carried out.	duration of frost. Shocks to be avoided.
TESTING.	Test pieces of concrete in form of cubes not less than 4 in. on edge or cylinders, not less than 4 in. diameter, having length not less than diameter tested before designing important work and during erection. Average of not less than 4 cubes or cylinders for each test. Tests to be made 28 days after molding. 1 : 2 : 4 concrete to have strength of not less than 2,400 lbs. per sq. in. Loading tests not to be made till 2 months after completion. Test load not to exceed 1½ times superimposed loading. Consideration to be given to adjoining parts of a structure in case of partial loading.	Testing blocks to be provided 8 in. or 12 in. wide, according to coarseness of aggregate. Portions of building in positions determined by building authority are to be exposed if desired so that mode of construction may be seen. Special tests may be made to determine hardness and strength. Test pieces may be cut out of finished building. If loading tests are considered necessary, they are to be carried out under instruction of representative of building authority. When a strip cut from a floor or decking is tested, the load shall be uniformly distributed and shall not exceed the	Conditions of tests and time that shall elapse before structures are brought into use must be inserted in contract, and also the maximum deflections as far as practicable. The time to elapse before use of structures must be 90 days for structures of primary importance, 45 days for ordinary constructions and 30 days for floors. Measurements to be taken during tests which are likely to be of scientific interest to engineers. Test loads on floors shall be the dead and superimposed loads acting over the whole area of the floor, or at least upon a complete panel. The loads to be left on for at least 24 hours, and	Test loads to be at least 50% greater than working loads allowed in calculations. Test loads not to be put on until 45 days have been allowed for setting. If possible deflections of different stages of loading to be noted.	Breaking tests of whole or part to be made on request. No test before expiration of six weeks after completion of ramming. Loading to be such that effect is same as dead load plus 1½ specified superimposed load. No cracks or permanent deformations. For breaking tests load to be gradually increased. Breaking load not to be less than 3½ times the total dead and superimposed load, less the weight of the member.

Subject	*A (Great Britain)*	*B (Germany)*	*C (France)*	*D (Switzerland)*	*E (Austria)*
Testing—(cont.)	No test load to be applied which would cause metal to be stressed more than ⅔ of its elastic limit.	weight of the strip and twice the working load. If strip is tested in situ, the above loading shall be increased by one-half.	deflection to cease after 15 hours.		
LOADING.	Weight of concrete to be taken as 150 lbs. per cu. ft. Weight of any covering to floors must be added to dead load. Superimposed load should be multiplied by 1½ for public halls, factories, workshops, &c., and by 2 for floors carrying machinery, roofs of vaults, under passage ways, courtyards, &c. Columns in buildings supporting three or more floors. For supports of roof and top floor, the full load. For support of 1st floor below top add to foregoing 0.90 load on this floor. For suport of 2nd floor below top, add to foregoing 0.80 load on this floor, and so on until for supports of 5th floor below top, and all other floors, add to the load calculated as above for the higher floors 0.50 load on the floor under consideration.	Weight of concrete shall be taken as 150 lbs. per cu. foot, unless different weight is determined definitely. Weight of any covering to floor must be added to dead load. For parts of structures subjected to considerable vibration or to greatly varying loads as floors of public halls, dancing rooms, factories or workshops, superimposed load to be multiplied by 1½. For parts subjected to heavy shocks, as roofs of vaults, under passage ways or courtyards, the superimposed load to be multiplied by 2.	The loads on roofs to be in accordance with Ministerial regulations of Feb. 17th, 1903, dealing with metallic roofs for railways, unless exceptions are justifiable. Floors and other parts of buildings, retaining walls, walls of reservoirs or conduits under pressure where affecting public safety, to be designed for maximum loads they may have to carry.	Weight of any covering, &c., to be added to dead load. In determining superimposed load allowance to be made for any shock or vibration it may produce.	*Nil*
BENDING MOMENTS, &c.	Span of beams or continuous floor slabs to be from center to center of supports. Span for slabs supported at ends clear span plus thickness of slab.	Span for beams to be free opening plus one support. Span of continuous decking to be distance from center to center of supports. For freely supported decking the clear span plus	For freely supported or continuous beams usual values may be applied. For partially fixed ends the bending moment at center of span for uni-	Most unfavorable disposition of loading to be allowed for. In continuous or encastre beams the bending moments at center of spans not to be less than ⅔ the	Spans for freely supported and continuous beams to be from center to center of support. Beams extending over several supports must be computed as for continu-

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Bending Moments—(cont.)	Bending moments where l = span in feet and w load per lineal foot. Beam or slab freely supported $\frac{wl^2}{8}$ foot lbs. Continuous beams or slabs or those fixed at ends if reinforced near upper surface at supports. If continuity or fixing is absolute, $\frac{wl^2}{24}$ at center of span and— $\frac{wl^2}{12}$ over supports generally, in building construction center bending moment should not be less than $\frac{wl^2}{12}$ Bending moments over supports to correspond with bending moment at center of span.	the thickness of the decking. Bending moments and reactions to be determined by formulæ for freely supported or continuous beams according to mode of support and distribution of load. For continuous decking bending mo ent at center of panel is to be taken as 4/5 of that which would exist in a freely supported panel, unless the moments and reactions can be ascertained. Above rule holds good for beams, excepting that no end moment is to be taken into account unless special arrangements have been made to fix the ends.	formly distributed load to be $\frac{wl^2}{10}$ If L and B are the spans of a rectangular slab the bending moment as for a beam of span B can be decreased by co-efficient $\frac{1}{1+2\frac{B^4}{L^4}}$ or span L the bending moment as for beam of span L with the co-efficient of reduction of $\frac{1}{1+2\frac{L^4}{B^4}}$	moments at the supports, due to the loading and amount of fixing and reinforcement over supports is to be provided. If amount of fixing cannot be determined, the moment at center of span must not be less than 20% that for a freely supported beam and that at supports to be at least half of that at center.	ous beams, incidental unfavorable loading being taken into account. Continuity not to be assumed as extending over more than three spans. Elastic deformation in supports of continuous beams to be taken into account. In beams the possibility of fixing moments at the supports must be provided for by suitable reinforcements. If L and B are spans of rectangular slab, and L is not more than one and a half B, slab being reinforced with equal area of metal both ways bending moment as for beam of span B can be decreased by co-efficient $\frac{L^4}{L^4+B^4}$
ALLOWABLE STRESSES.	Concrete to be not weaker than 1 : 2 : 4 to have crushing strength of 2,400 to 3,000 lb. per sq. in. Co-efficient of elasticity concrete E_c = 2,000,000 lb. per sq. in. Ditto steel E_s = 30,000,000 lb. per sq. in. $\frac{E_s}{E_c} = 15$	$\frac{E_s}{E_c} = 15$	$\frac{E_s}{E_c} = 8$ to 15 Minimum when diameter of longitudinals 1/10 least dimension of member, ties or transverse reinforcements spaced apart a distance equal to least dimension of member. Maximum when diameters of bars equal to 1/20 least dimension of member and spacing of ties, &c., ⅓ least dimension of member.	$\frac{E_s}{E_c} = 20$	Co-efficient elasticity of concrete in compression, 1,990,000 lb. per sq. in. Co-efficient elasticity of steel in tension or compression, 29,850,000 lb. per sq. in. $\frac{E_s}{E_c} = 15$

Subject	A (Great Britain)	B (Germany)	C (France)	D (Switzerland)	E (Austria)
Allowable Stresses—(cont.)	Resistance of concrete in tension to be neglected. Concrete in beams, &c., 600 lb. per sq. in. Concrete in simple compression 500 lb. per sq. in. Concrete in shear 60 lb. per sq. in. Adhesion of concrete to metal 100 lb. per sq. in. Steel in tension, ultimate resistance not less than 60,000 lb. per sq. in. } 15,000 to 17,000 lb. per sq. in. Ends of bars in beams, &c., should be split open or bent at ends or other security provided against slipping. When stronger concrete used the resistance for beams to be taken at ⅛ ultimate, and in simple compression 1/5 ultimate. When stronger steel used tensile resistance to be ½ that at elastic limit.	Resistance of concrete in tension neglected. Concrete in beams 1/5 ultimate compressive resistance. Concrete in simple compression 1/10 ultimate compressive resistance. Concrete in shear, 64 lb. per sq. in. or 1/5 ultimate. Adhesion of concrete to steel same as in shear. Steel on tension or compression not to exceed 17,000 lb. per sq. in. So far as possible reinforcements to be of such form that displacement relative to the concrete is prevented.	Resistance of concrete in tension taken into account for calculation of deformations but not resistance. Concrete in compression not to exceed 28% crushing strength of 8 in. cubes of plain concrete 90 days old. When hooped or when transverse or oblique reinforcement disposed to prevent swelling of concrete above resistance may be increased in proportion to volume of bars and their suitability of arrangement, but safe resistance to be never greater than 60% crushing strength. Concrete in shear and adhesion of concrete to steel 28% of crushing strength of concrete. Steel in tension and compression not more than ½ strength at elastic limit reduced to 40% for members such as slabs subjected to alternating stresses. For members subjected to stresses, varying within wide limits safe resistances to be reduced, but not more than 25%.	Resistance of concrete in tension neglected. Concrete in compression 498 lb. per sq. in. Concrete in shear 56 lb. per sq. in. Steel in tension (in beams) 14,223 lb. per sq. in. Steel in tension (in slabs) 17,068 lb. per sq. in. Steel in compression 9,956 lb. per sq. in.	Resistance of concrete in tension neglected in calculating strength. Concrete Working Stresses lbs. per square inch Weight of cement in lbs. to cubic yard of sand and stone: 720 / 535 / 428 Proportions in Volume: 1:3 / 1:4 / 1:6 Bending or Eccentric Loading — Compression: 570 / 512 / 454 Bending or Eccentric Loading — Tension: 341 / 327 / 305 Simple Compression: 398 / 355 / 312 Shearing: 64 / 64 / 50 Adhesion: 78 / 78 / 64 Soft Steel Tension .. 13,500 Medium Steel " 14,200 Steel Shear ..... 8,530 Stirrups or transverse connections must be provided in sufficient numbers. Ends of reinforcing bars must be so shaped to ensure security against slipping unless the surface of the bar is so formed as to resist displacement relative to the concrete. If any other proportions used for concrete safe resistance are to be cal-

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Allowable Stresses—(cont.)					culated by rectilinear interpolation from the values for the weight of cement per cu. yd. of sand and stone as given above.
RULES FOR CALCULATION.	The deformation in a piece subjected to bending directly proportional to the distance from the neutral axis—*i. e.*, straight line stress—strain relation. Width of slab acting with T beam to be not more than ⅓ span or ¾ distance center to center of reinforced ribs, whichever is least. Shearing and adhesion stresses should be calculated and special provision made to resist these if necessary. Calculations given for eccentrically loaded columns and for long columns vertically loaded when the length exceeds 18 times least diameter. Calculations for long columns made by Gordon's formula with value for constant of 32,000. In T-beams, when neutral axis falls below bottom of slab the resistance of the concrete in the rib is neglected. The thickness of slab for T-beams determined by stiffness required for	Straight line stress—strain relation. Width of slab acting with T-beam to be not more than ⅓ span. Shearing and adhesion stresses to be calculated and special provision made to resist these if necessary. For columns the possibility of eccentric loading is to be taken into account. Transverse connections in columns not to be further apart than 30 times diameter of rods. Calculations for flexure of columns to be made whenever height exceeds 18 times least diameter. Euler's formula to be used for calculating flexure of columns, a factor of safety of 5 being allowed when calculating for flexure of the reinforcements, no support being allowed from concrete and 10 when calculating for whole column. In T-beams when neutral axis falls below bottom of slab the resistance of the concrete in the rib is neglected.	Straight line stress—strain relation. Width of slab acting with T-beam to be not more than ⅓ span or ¾ distance center to center of reinforced rib, whichever is least. Shearing and adhesion stresses to be calculated and special provision made to resist these if necessary. Columns calculated for eccentric loading. Calculations given for hooped columns. Calculations for flexure to be made for columns when height exceeds 20 times least diameter. Account to be taken of temperature and shrinkage stresses as well as loading if structure cannot expand and contract freely.	Straight line stress—strain relation. Shearing stresses to be calculated and if exceeded reinforcement to be introduced by bending up bars or otherwise to resist it. For columns any eccentric loading must be taken into consideration. The reinforcement is to be calculated to resist bending as if unsupported by concrete by Euler's formula with factor of safety of 4, half distance between the bindings being assumed as the unsupported length.	In pieces subject to flexure maximum tensile stress in concrete to be calculated on assumption of a modulus of elasticity of 796,000 lb. per sq. in. for concrete in tension. Shearing and adhesion stresses calculated, and special provision made to resist these if necessary. If deformed bars used adhesive resistance may be assumed as exceeding values given above by 10%. Column reinforcement calculated separately for flexure, ties not spaced farther apart than least diameter of column. Sectional area of metal in columns not less than 0.8% of total sectional area of column. If sectional area of metal exceeds 2% of total sectional area of column, the excesses beyond 2% only be taken into account to extent of ¼ its value. Eccentric loading of columns to be taken into account. Calculations for flexure

Subject	*A (Great Britain)*	*B (Germany)*	*C (France)*	*D (Switzerland)*	*E (Austria)*
Rules for Calculation—(cont.)	floor in general, it is from 1/12 to 1/18 of the span.				made for columns when height exceeds 20 times least radius of gyration. Free length being that between fixed ends. Hooped column formulæ.
GENERAL REGULATIONS.	*Nil*	Special examination of building authority to proceed erection of any building or portion of building. Application for permission for erection must be accompanied by drawings, statical calculations, and descriptions. Description must state origin and nature of materials to be used in concrete, and the proportions in which they are to be mixed. Applications to be signed by building owner and the contractor charged with the erection.	Quality and proportions of concrete to be specified in the contract.	Designs prepared so that drawings and calculations shows clearly general arrangements, allowed loads, calculations of strength, and details of parts. It is permissible to depart from the regulations if the variations are based on actual trial and upon the opinions of competent persons.	

PROPOSED STANDARD BUILDING REGULATIONS FOR THE USE OF REINFORCED CONCRETE.*

I. General.

Definition of Reinforced Concrete.

1. The term "Reinforced Concrete" shall be understood to mean an approved concrete which has been reinforced by metal in some form so as to develop the compressive strength of the concrete.

Class of Buildings.

2. Reinforced concrete may be used for all classes of buildings if the design is in accordance with good engineering practice and stresses are figured as indicated in these regulations.

Height of Buildings.

3. There shall be no limit upon the height of buildings of reinforced concrete except as limited by the requirements in these regulations.

Plans.

4. Before permission is granted by the Building Department to erect any reinforced concrete building, complete plans, accompanied by specifications, signed by the engineer and architect, must be filed with the Building Department and remain on file for public inspection until the building is completed.

5. The Building Department shall have access to the computations, which shall give the loads assumed separately, such as dead and live loads, wind and impact, if any, and the resulting stresses.

Specifications.

6. The specifications shall state the qualities of the materials to be used for making the concrete, and the proportions in which they are to be mixed.

7. Upon the completion of the building the engineer and architect shall issue, under the approval of the Building Department, signed certificates, to be posted on each floor of the building, stating the safe carrying capacity per square foot.

Records.

8. There shall be kept an exact record of the progress of each operation where the same can be inspected by the Building

* These Proposed Regulations were submitted to letter ballot, which was canvassed on May 10th, 1909, and were adopted by a majority of 18 votes. In view of this slight majority and of the fact that the members did not receive adequate time to properly consider these Regulations before the Annual Convention, the Executive Board has decided to submit them for reconsideration of the Association at the Sixth Annual Convention.—Ed.

(d.) TABULATION OF BUILDING CODE REQUIREMENTS IN THE P

(Appendix to Report of Committee on Insurance, Laws

	New York, Borough of Manhattan.	Borough of Brooklyn.	Buffalo, N. Y.	Boston, Mass.	Chicago, Ill.	Denver, Col.	Louisville, Ky.	Toledo, Ohio.
Kind of Cement.	Portland.	Portland.	Portland.	Portland.	Portland.	Portland.	Natural or Portland.	Portland.
Test tension, lb. {1 day in air. / Neat briquette.}	120	175			200	200		300
Test tension, lb. {1 day in air. / 6 days in water.}	300	500	500		500	500		500
Test tension, lb. {1 day in air. / 27 days in water.}		600	600		600	600		600
Tests—Fineness, constancy of volume, etc.	A. S. C. E.	Special rules	A. S. C. E.		A. S. C. E.	A. S. C. E.	A. S. T. M.	A. S. C. E.
Concrete Mixture	1–2–4	1–2–5 1–2–4	1–2–5	1–2½–5	1–2–5 1–3–5	1–2–3	1–2–4	1–2–4
Method of mixing	Wet	Wet	Wet		Wet	Wet		Wet
Size of stone in {Foundations, / Columns, / Slabs,}	¾	2 in. ¾	¾		¾ 1	2 2 ¾	2 1½ 1	¾
Concrete test. {Compression after 28 days per sq. in., lb.}	2,000	2,000	2,000	2,000				2,000
Extreme fibre stress per sq. in. for concrete in compression, lb.	500	500	500	500 to 600	600	500	700	500
Concrete in tension per sq. in., lb.	None	None	None	None	None	None	None	None
Concrete in direct compression, lb.	350	400	350	350	400	450	700	350
Shear in concrete per sq. in., lb.	50	75	50	60	75	50	30	50
Adhesion of concrete to steel, lb.	50	75	50	60	75	75	30	50
Ratio of moduli of elasticity	1/12	1/12	1/12	Beams and slabs 1/15 cols. 1/10	1/12	1/15		1/12
Column stress, lb.—Horizontal hooping		600 to 750						700
Column stress, lb.—Spiral hooping	Special formula	1,000c 6,000s			800c			
Columns, ratio of height to least diam.	1/12	1/12	1/10	120 times least rad. of gyr.	1/12	1/15		1/12
Insulation—Columns, in.	*2	2		1½	Fire proof 2 / Non fire-proof 1½	1½	2	
Insulation—Beams, in.	*1½	1½ times diam. of bars to 1½ in. max.		1½	Fire proof 2 / Non fire-proof Bottom 1½ Sides 1½	1½		
Insulation—Slabs, in.	*1	1½ times diam. of bars to 1½ in. max.		¾	Fire proof 1 / Non fire-proof ¾	½		
Insulation—Walls, in.		Not less than 1 in.						
Tensile stress per sq. in. for steel, lb.	16,000	16,000	16,000	16,000	½ elastic limit 18000 max.†	½ of elastic limit	12,000 to 18,000	16,000
Shear stress for steel, lb.	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Spacing of hoops in columns	Least width of col.	1½ times least width of col.	Least width of col.		Least width of col.	Least width of col.		Least width of c
Minimum thickness of concrete slabs, in.	3½	3½						
Width of slab allowed for figuring tee beams	10 times width of beam	10 times width of beam	10 times width of beam	⅓ span of girder	4 times depth of slab	5 times width of girder		10 times width girder
Deflection allowed on load test	3x load no sign of failure	Twice load 1/1/5 deflection	3x load no sign of failure		Twice load 1/1/5 deflection	Twice load 1/1/5 deflection		3x load no sign failure
Bending Moments—Beams	WL/8	WL/8	WL/8	Contin. WL/10	WL/8	WL/8		WL/8
Bending Moments—Continuous slabs	WL/10	WL/10	WL/10	WL/10	WL/10	WL/12		WL/10
B. M. for slabs supported on all four sides	WL/20	WL/20	WL/20		WL/20	WL/20		WL/20
Maximum percentage steel in beams								
Minimum percentage of steel in columns		2/1/5			2/1/5 max. 1/10			
Time of removal of centering for columns	Variable	Variable				4 days	10 to 15 days	
Time of removal of centering for beams	Variable	Variable			1 week	12 days	14 to 21 days	
Time of removal of centering for slabs	Variable	Variable			1 week	6 days	10 to 15 days	

Revised May 20, 1908.

* Rulings not set forth in code.

† Spacing of rods in beams, columns, girders, etc. = 1½ x dia. rod. (min.).

IN THE PRINCIPAL CITIES OF THE UNITED STATES.

Insurance, Laws and Ordinances.)

Toledo, Ohio.	San Francisco, Cal.	Royal Institute of British Architects.	National Fire Protection Association.	Rochester, N. Y.	Philadelphia, Pa.	Pittsburgh, Pa.§	St. Louis, Mo.	Baltimore, Md.
Portland.	Portland.	Portland.	Portland.	Portland.	Portland.	Portland.	Portland.	Portland.
300	.....	.....	300	.....	175	200	200	.....
500	.....	.....	500	.....	500	500	500	.....
600	.....	.....	600	.....	600	600	600	.....
A. S. C. E.	.....	.....	A. S. C. E.	.....	A. S. C. E.	A. S. C. E.	A. S. C. E.	.....
1–2–4	1–3–5 1–2–4	.....	1–3–5	1–2–5	1–2–4	1–2–4	1–2–4	1–2–4–400 1–2–5–350
Wet	Wet	.....	Wet	.....	Wet	Wet	Wet	Wet
¾	2 1 1	¾	¾	2	2 1½ 1	2 1½ 1	2 1½ 1	2 1
2,000	2,000	2,400	2,000	.....	2,000	2,000	2,000	2,000
500	500	600	500	.....	600	600	800	.....
None	None	None	None	None	None	None	None	None
350	450	500	350	230	500	500	500	500
50	75	60	50	.....	75	50	25	50
50	75	100	50	.....	50	50	50–30	60
1/12	1/12	1/12	1/12	.....	1/12	1/12	1/12	1/12
700	.....	.....	6,000s 350c	.....	‡7,500s 1,000c	6,000s 600c	7,500s 500c	600c
.....	700	.....	.....	.....	Special formula	Special formula	Special formula	.....
1/12	1/12	.....	1/12	.....	1/12	1/12	1/12	1/12
.....	1½	2	4 times diam. of bar to 4 in.	.....	2	2	2	1½
.....	1½ times diam.	1½	4 times diam. of bar to 4 in.	.....	2 on bottom, 1½ on sides	1½	1½	1
.....	1	1	1	.....	1	1	1	¾
.....	1	1	.....	.....	1½	1½	1½	.....
16,000	½ of elastic limit	15,000 to 17,000	½ of ultimate strength	16,000	16,000	16,000	14,000 20,000	16,000
10,000	10,000	.....	10,000	10,000	10,000	10,000	10,000	10,000
Least width of col.	Least width of col.	.....	Least diam. of col.	.....	‡Least width of col.	Least width of col.	Least width of col.	12
.....	3½	.....	.....	.....	.....	.....	.....	4
10 times width of girder	5 times thickness of slab	½ of beam span	.....	.....	20 times thickness of slab	10 times width of beam	½ span of beam	.....
3x load no sign of failure	Twice load 7/10 deflection	.....	.....	.....	.....	.....	.....	2x live load with no sign of cracks
WL/8	WL/8	WL/8	WL/8	.....	WL/8	WL/8	WL/8	WL/10
WL/10	WL/12	WL/12	WL/10	.....	WL/10	WL/10	WL/10	WL/10
WL/20	WL/20	.....	WL/20	.....	WL/20	WL/20	WL/24	.....
.....	.....	.....	.....	.....	.....	.....	.....	Straight line formula 1%
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	8 to 28 days	1 to 60 days	7 days.	Not less than 4 days	.....	10 days	.....
.....	.....	Depending on weather conditions	Depending on weather conditions	.....	Not less than 2 weeks	.....	Depending on weather conditions	.....
.....	.....	.....	.....	.....	Not less than 1 week	.....	.....	.....

rod. (min.).

‡ Hooping to be approved.

§ Uses Manhattan code.

This table is published through the courtesy of the General Fireproofing Co., Youngstown, Ohio.

Department. These records shall show the date of placing of all the concrete and date of removal of the forms, and must be turned over to the Building Department when the building is completed.

Walls.

9. Reinforced concrete walls may be used in place of brick or stone walls with reduced thickness. Curtain walls shall not be less than four (4) inches thick.

10. Concrete walls must be reinforced in both directions. The maximum spacing of reinforcing bars shall be 18 in. centers, reinforcement in either or both faces of the wall being considered. Reinforcement shall be not less than one-fourth of 1 per cent.

Tile and Joist Construction.

11. Wherever floor constructions are built with a combination of tile or other fillers between joists, the following rules regarding the dimensions and methods of calculations of construction shall be observed:

(*a*) Ratio of minimum depth to clear span of joist shall not be greater than one to eighteen.

(*b*) Wherever a portion of the slab above the tile joist shall be considered as acting as a Tee-beam section, the slab portion must be cast monolithic with the joist and must have a minimum thickness of at least 2 in. on all spans. Otherwise, all regulations applying to Tee beams shall apply to tile and joist construction.

(*c*) Where the joists are figured as rectangular beams, in accordance with the standard regulations for this type of beams, the slab shall be considered as independent of the structural part of the building.

(*d*) Wherever porous tiles, or other materials which by their nature will absorb water from the concrete, are used between the joists, care must be taken to thoroughly saturate the tiles, or other materials, with water immediately before the concrete is placed.

(*e*) Reinforcement for slabs over joist construction below 30 in. centers need not be closer than 24 in. in each direction.

II. MATERIALS.

a. CEMENT.

Cement.

12. Only Portland cement shall be used in reinforced concrete structures. Portland cement shall meet the requirements of the

Standard Specifications for Cement of the American Society for Testing Materials. (See Standard No. 1 of the National Association of Cement Users.)

13. Tests of cement used in building operations shall be made from time to time under the supervision of the Building Department in accordance with the preceding specifications. No brand of cement which has not met these requirements shall be used.

b. AGGREGATES.

Aggregates.

14. Extreme care shall be exercised in selecting the aggregate for mortar and concrete, and careful tests must be made, where any doubt exists, of the materials for the purpose of determining their qualities and the grading necessary to secure maximum density or a minimum percentage of voids.

15. *Fine aggregate* shall consist of sand, crushed stone or gravel screenings, passing when dry a screen having one-quarter inch diameter holes, and not more than six per cent. passing a sieve having 100 meshes per lineal inch. It shall be of clean, silicious material free from vegetable loam or other deleterious matter.

16. Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets should show a tensile strength of at least 70 per cent. of the strength of 1 : 3 mortar of the same consistency made with the same cement and standard Ottawa sand.

17. *Coarse aggregate* shall consist of inert material, such as crushed stone, or gravel, which is retained on a screen having one-quarter inch diameter holes, the particles shall be clean, hard, durable and free from all deleterious material. The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not prevent the concrete fully surrounding the reinforcement or filling all parts of the forms.

18. The maximum size for reinforced concrete shall be such that all the aggregate shall pass a one and one-quarter inch diameter ring.

Cinder Concrete.

19. *Cinder* concrete shall not be used for reinforced concrete structures; it may be used for fireproofing. Where cinders are used as the coarse aggregate they shall be composed of hard, clean, vitreous clinker, free from sulphides, unburned coal or ashes.

c. REINFORCEMENT.

20. *Medium steel* for reinforcement of concrete shall be made from billets and shall conform to the requirements of the specifications for Structural Steel adopted by the American Railway Engineering and Maintenance of Way Association. **Reinforcement.**

21. *High Carbon Steel* shall be made entirely from new billets, having (1) a desired ultimate strength of 88,000 lbs. per sq. in. with an allowable range of 8,000 lbs. from the desired ultimate strength, (2) an elongation in per cent. in eight (8) inches of $\frac{1,200,000}{\text{ultimate strength}}$ and (3) capable of cold bending 180 degrees around four (4) diameters without fracture.

22. Where wire or rods up to one-quarter inch diameter are used for reinforcement of slabs or for the prevention of shrinkage cracks, either material manufactured from the Bessemer billet (not re-rolled rails) or drawn from basic open hearth steel may be used.

III. DETAILS OF CONSTRUCTION.

a. MIXING.

23. *General.* The ingredients of concrete shall be thoroughly mixed to the desired consistency, and the mixing shall continue until the cement is uniformly distributed and the mass is uniform in color and homogeneous. **Mixing.**

24. Methods of measurement of the proportions of the various ingredients, including the water, shall be used, which will secure separate uniform measurements at all times. **Measuring Proportions.**

25. *Machine Mixing.* When the conditions will permit, a machine mixer of a type which insures the proper mixing of the materials throughout the mass shall be used.

26. *Hand Mixing.* When it is necessary to mix by hand, the mixing shall be on a water-tight platform, and especial precautions must be taken to turn the materials until they are homogeneous in appearance and color.

27. *Consistency.* The materials must be mixed wet enough to produce a concrete of such a consistency as will flow into the forms and about the metal reinforcement, and which, on the other

hand, can be conveyed from the mixer to the forms without separation of the coarse aggregate from the mortar.

28. *Retempering* mortar or concrete, *i. e.*, remixing with water after it has partially set, shall not be permitted.

b. PLACING OF CONCRETE.

Placing of Concrete.

29. *General.* Concrete shall be placed in the work immediately after mixing and deposited and rammed or agitated by suitable tools in such a manner as to produce thoroughly compact concrete of maximum density. No concrete should be placed until the reinforcement has been placed and firmly secured by wiring or other methods to prevent displacement.

30. The faces of concrete exposed to premature drying shall be kept damp for a period of at least seven days.

31. Before placing the concrete care shall be taken to see that the forms are substantial and thoroughly wetted and the space to be occupied by the concrete free from debris. When the placing of the concrete is suspended, all necessary grooves for joining future work shall be made before the concrete has had time to set.

32. When work is resumed, concrete previously placed shall be roughened, thoroughly cleansed of foreign material and laitance, drenched and slushed with a mortar consisting of one part Portland cement and not more than two parts fine aggregate.

33. *Placing in water.* Concrete should not be placed in water, unless unavoidable. Where concrete must be placed under water, unusual care must be taken to prevent the cement from being floated away.

34. *Freezing Weather.* Concrete shall not be mixed or deposited at a freezing temperature unless special precautions are taken to avoid the use of materials containing frost or covered with ice crystals, and to provide means to prevent the concrete from freezing after being placed in position and until it has thoroughly hardened.

c. PLACING OF REINFORCEMENT.

Placing of Reinforcement.

35. The reinforcement shall be accurately located in the forms and secured against displacement.

d. JOINTS.

Joints.

36. *Reinforcement.* Wherever it is necessary to splice reinforcement by means of lapping, the length of the lap shall be determined upon the basis of the safe bond stress and the stress in the bar at the point of splice; or a connection shall be made between the bars of sufficient strength to carry the stress. Splices at the point of maximum stress must be avoided.

37. In columns large bars shall be properly butted and spliced. Small bars may be treated as indicated in paragraph 36.

38. *Concrete.* Reinforced concrete work shall be stopped at such points that the joints will have the least possible effect on the strength of the structure. Footings shall be cast to their full depth at one operation.

(*a*) *Columns.* Work in columns shall be stopped at the underside of the lowest beam or girder bearing on the column.

(*b*) *Beams and Girders.* Construction joints in beams and girders shall be vertical and within the middle third of the span. Any concrete which may run past the bulkheads must be cleaned up before the concreting of the next section is started. Where brackets are used, the bracket shall be considered as a part of the beam or girder.

(*c*) *Slabs.* Construction joints in slabs shall be near the center of the span. No joint will be allowed between slab and beam or girder.

e. REMOVAL OF FORMS.

Removal of Forms.

39. Under no consideration shall forms be removed until the concrete has hardened sufficiently to permit their removal with safety.

40. *Floor Slabs and Beams.* Forms shall not be removed from floor slabs in less than seven days. Sides of beams may be removed at the same time as the floor slabs provided original supports under beams and girders are left in place.

41. *Columns.* Where original supports remain under beams and girders coming to the columns, the forms shall not be removed from the columns in less than four days.

Removal of Supports from Beams and Girders.

42. *Beam and Girder Supports.* The original supports for all beams and girders must remain in place at least ten days, but all beams and girders having more than thirty feet span from

center to center of support shall be considered as special cases and shall be subject to inspection of the Building Department before removal of supports.

IV. DESIGN.

a. GENERAL ASSUMPTIONS.

43. *Internal Stresses.* As a basis for calculations for the strength of reinforced concrete construction, the following assumptions shall be made:

(*a*) A plane section before bending remains plane after bending.

(*b*) The modulus of elasticity of concrete in compression within the usual limits of working stresses is constant.

(*c*) In calculating the moment of resistance of beams the tensile stresses in the concrete shall be neglected.

(*d*) Perfect adhesion is assumed between concrete and reinforcement. Under compressive stresses the two materials are therefore stressed in proportion to their moduli of elasticity and their distance from the neutral axis.

(*e*) The ratio of the modulus of elasticity of steel to the modulus of elasticity of concrete shall be assumed to be 15.

(*f*) No allowance shall be made for tension in concrete.

(*g*) Initial stress in the reinforcement due to contraction or expansion in the concrete may be neglected.

(*h*) In columns the ratio of least diameter to height shall be taken as one-fifteenth. Greater ratios shall be deduced by satisfactory column formulæ.

44. *Length of Beams and Slabs.* The span length for beams and slabs shall be taken as the distance from center to center of supports, but shall not be taken to exceed the clear span plus the depth of beam or slab. Brackets shall not be considered as reducing the clear span.

45. *Length of columns* shall be taken as the maximum unsupported length.

46. Where *slabs and beams* are figured as simple beams the length shall be considered as the clear distance between supports excluding brackets.

b. LOADS.

47. The *dead load* shall include the weight of the structure and all fixed loads and forces. **Loads.**

48. The weight of the reinforced concrete shall be taken as 150 pounds per cubic foot.

49. The *live load* shall include all loads and forces which are variable.

The minimum live load for floors and roofs shall be as generally provided by building codes.

50. *Roof and Floor Loads.* The roof shall be figured to carry 30 pounds live load per square foot unless otherwise noted.

51. A reduction of live load coming to the column supporting the floor below the roof of 5 per cent. to be allowed and a further reduction of 5 per cent. of the live load of each story below until the total reduction shall amount to 50 per cent. of the live load of any floor, after which all loads shall be figured net to the foundations. These reductions shall not apply to storage warehouses.

52. *Reduction of Loads.* No reduction of loads shall be allowed for figuring floor slabs.

53. No reduction of loads shall be allowed for figuring beams.

54. A reduction of 15 per cent. live load may be allowed in figuring the girders, except in buildings used for storage purposes.

55. In assuming the load coming to the columns all beams and girders shall be considered as carrying a net load consisting of 100 per cent. each of live and dead load, subject to the above reductions.

c. BENDING MOMENTS.

56. *Slabs.* The bending moment of slabs uniformly loaded and supported at two sides only shall be taken as $\frac{1}{8}$ wl^2, where w = unit load and l = span. **Bending Moments.**

57. *Continuous Slabs.* For interior slabs overhanging two or more supports the bending moment shall be taken as $1/12$ wl^2. The reinforcement at the top of the slab over supports must equal that used at the center. The reinforcement in the bottom of the slab must equal at least $\frac{1}{4}$ of that used at center.

58. *Slabs Reinforced in Both Directions.* Slabs that are reinforced in both directions and supported on four sides and fully reinforced over the supports (the reinforcement passing into the adjoining slabs) may be figured on the basis of bending moments equivalent to $\frac{wl^2}{F}$ for load in each direction. When span under consideration is not continuous, $F = 8$; when continuous over one support, $F = 10$; when continuous over both supports, $F = 12$. The distribution of the loads to be determined by the formula:

$$r = \frac{b^4}{L^4 + b^4}$$

in which r equals proportion of load carried by the transverse reinforcement, L equals length of span, and b equals breadth of slab.

59. The slab area may be reduced by one-half, as above figured, when the reinforcement is parallel to and not farther from the supports than one-quarter of the shortest side.

The reinforcement spanning the shortest direction shall be below the reinforcement spanning the longer direction, and shall not be further apart than 2½ times the thickness of the floor including the finish.

Simple Beams.

60. *Simple Beams.* The bending moment of beams supported at the ends only shall be figured as of simple beams.

Partially Restrained Beams.

61. *Partially Restrained Beams.* Beams supported at one end and continuous at the other to be figured partially restrained with a bending moment of eight-tenths (0.8) that of a simple beam.

When the overall vertical distance of the tension members is greater than one-sixth of the total depth of the beam the stresses in each member shall be computed in proportion to the distance from the neutral axis.

62. Beams supporting rectangular slabs reinforced in both directions shall be assumed to take the following load: The beams on which the shortest sides of the slab rest shall take the load of that portion of the slab formed by the isosceles triangle having this side as its base and half this side as its height. The load from the remaining portion of the slab shall go to the beams on which the long side of the slab rests.

63. *Continuous Beams.* When beams or girders are continuous over two or more supports, the interior beams may be considered as partially restrained, and the bending moments at the center and support figured as two-thirds (2/3) that of a simple beam, unless the concrete at the bottom of the beam at the support shall by this consideration receive excess compression. **Continuous Beams.**

64. *Tee Beams.* In beam and slab construction, an effective metallic bond should be provided at the junction of the beam and slab. When the principal slab reinforcement is parallel to the girder, transverse reinforcement shall be used extending over the girder and well into the slab. **Tee Beams.**

65. Where adequate bond between slab and web of beam is provided, the slab may be considered as an integral part of the beam, but its effective width shall not exceed one-eighth (⅛) of the span length of the beam on either side of the beam.

66. In the design of Tee beams acting as continuous beams, due consideration should be given to the compressive stresses at the support at the bottom of the beam.

d. WORKING STRESSES.

67. Concrete composed of materials meeting the requirements of these regulations, mixed in proportion of one part of cement and six parts of aggregate (fine and coarse), shall develop a compressive strength of 2,000 pounds per square inch in 28 days when tested as 8 in. diameter cylinders 16 in. long under laboratory conditions of manufacture and storage, using the same consistency as is used in the field. When the proportion of cement is increased, using the best quality of aggregates, an increase may be made in all working stresses proportional to the increase in compressive strength at 28 days, as determined by actual tests. On this basis the following working stresses shall be allowed in construction: **Concrete.**

68. *Bearing* compression, 650 pounds per square inch.

69. *Compression* in extreme fiber, 650 pounds per square inch. With increase of 15 per cent. near supports in continuous beams.

70. *Axial compression* in columns *without hoops,* 450 pounds per square inch and 6,750 pounds per square inch or vertical reinforcement.

71. *Axial compression* in columns with 1 *per cent. of hooping*, 540 pounds per square inch, and 6,750 pounds per square inch of vertical reinforcement.

72. *Axial compression* in columns with 1 *per cent. hooping* and 1 *to* 4 *per cent. of vertical reinforcement*, 650 pounds per square inch on the concrete and 9,750 on the vertical reinforcement.

Bars composing longitudinal reinforcement shall be straight and shall have sufficient lateral support to be securely held in place until the concrete is set.

The clear spacing of bands or hoops shall be not greater than one-fourth the diameter of the enclosed column. Adequate means must be provided to hold bands or hoops in place so as to form a column, the core of which shall be straight and well centered.

Bending stresses due to eccentric loads must be provided for by increasing the section until the maximum stress does not exceed the values above specified.

73. *Compression* on columns reinforced with *structural steel units* which thoroughly encase the concrete core, 540 pounds per square inch on the concrete and 8,100 pounds per square inch on the structural steel.

74. *Web Stresses.* In calculating web reinforcement the concrete shall be considered to carry 40 pounds per square inch, the remainder to be provided for by means of reinforcement in tension.

Members of web reinforcement shall be embedded in the compression portion of the beam so that adequate bond strength is provided to fully develop the assumed strength of all shear reinforcement. They shall not be spaced to exceed three-fourths (¾) of the depth of the beam in that portion where the shearing stresses exceed the allowable shearing value of the concrete. Web reinforcement, unless rigidly attached, shall be placed at right angles to the axis of the beam and looped around the extreme tension member.

75. *Bond* between plain bars and concrete, 80 pounds per square inch of surface of bar; where adequate mechanical bond is provided the stress shall not exceed 150 pounds per square inch of surface of bar.

76. The *ratio of modulus of elasticity* of concrete to steel shall be considered as one to fifteen. **Ratio of Moduli of Elasticity.**

77. The allowable *tensile stress* in reinforcement to be 16,000 pounds per square inch for medium steel and 20,000 pounds per square inch for high carbon steel with adequate mechanical bond. **Reinforcement.**

78. The *compressive stress* in the steel reinforcement to be fifteen times the allowed compression in concrete in which the steel is embedded.

e. FIREPROOFING.

79. The main reinforcement in columns shall be protected by a minimum of two inches of concrete, reinforcement in girders and beams by one and one-half inches and floor slabs by one inch. **Fireproofing.**

DISCUSSION ON INSURANCE.

Mr. Humphrey.

PRESIDENT RICHARD L. HUMPHREY.—I have understood that in some parts of the country the rates of insurance on cement block construction are high. We have not been able to obtain many such rates and the members should write the Association about cement block buildings in their towns and give the rates of insurance.

It should be borne in mind that a great many conditions affect the insurance rate. The character of the contents is always taken into consideration,—also the character of the surrounding buildings and of the exposures, that is, whether the buildings are protected against fire from without. Of course, the character of protection provided inside of the building affects the rate.

The report of the Committee on Insurance cites the case where a building of reinforced concrete construction, by reason of its abutting against a wooden structure with a fireproof wall, carries a comparatively high rate. The insurance company is writing the risks as a business and they are guessing on the possibility of fire and the probable loss. They have a very conservative way of guessing, and you cannot blame them, because if they do not guess conservatively they lose money. It is manifest that these companies are not in the business to lose money.

Mr. Genther.

MR. WILLIAM J. GENTHER.—I was talking to an insurance inspector who stated that they were not anxious to carry cement block buildings at all. He referred to a couple of buildings, of single face block, near Olean, in which at the height of a fire the wall simply opened up, separated entirely. He said that was one reason why they did not care. He knew nothing about the construction of buildings, but in that case they had insurance on the building and that was his objection, although this case may have been one of faulty construction.

In our town, Despatch, N. Y., just east of Rochester, we have been able to obtain a better rate on cement block construction than

on frame or brick. I do not know the reason, but our insurance company gives us a rate of .85 per cent. on cement block construction as against 1.75 on wood and 1.25 per cent. on brick, at no solicitation whatever. We have obtained the .85 per cent. rate on a bakery, a class of buildings it is sometimes very hard to get insurance on at all. **Mr. Genther.**

MR. DANA G. CHANDLER.—I built a concrete block factory and the companies want about $1.25 for insurance on that. The steam curing plant I am installing makes some difference. The only wood in the construction is the roof. **Mr. Chandler.**

PRESIDENT HUMPHREY.—How about the character of the surroundings? Have you any frame sheds or anything like that around it? **Mr. Humphrey.**

MR. CHANDLER.—There are no buildings near except a small one right adjoining in which I keep my cement. **Mr. Chandler.**

We had a fire last summer in which part of the town was destroyed. A big elevator burned down on one side of a little concrete block bank building and a good-sized hotel for a small town on the opposite side. The cashier of the bank told me that they had obtained a better insurance rate after the fire. The windows on one side of the building and one door on the back end burned out. The roof was covered with Rubberoid roofing which partly melted off and a woodshed on the back end burned entirely off. It was only necessary to put in new doors, new windows, and retar the roof. The bank building is just as good to-day as the day it was built. I am told the building would not have stood the fire if they could have used water to play on the flames. However, aside from the burning of the windows you would not know the building had ever seen a fire. A group of about 14 or 15 buildings burned down and this little building stood right through the whole fire.

PRESIDENT HUMPHREY.—The question of whether a building has passed successfully through a fire or not is entirely a matter of judgment. The insurance interests generally look at a fire with a great deal more critical eye than perhaps a friend of the type of structure that is being investigated and find defects which a person who is not overly anxious or who is possibly biased does not see. In a number of photographs sent me recently of fires throughout the country, while it is true that **Mr. Humphrey.**

Mr. Humphrey. frame structures were destroyed around the concrete block building, the statement that the blocks came out with flying colors is subject to qualifications since there would be a telegraph pole unburned, or some inflammable structure near the building which was not damaged, showing that the heat could not have been very intense, otherwise that structure would have been charred. At the same time there is no question but that structures in many parts of the country have certainly stood the fire tests extremely well.

Mr. Longacher. MR. P. T. LONGACHER.—I contracted to construct a factory building 40 x 100 ft., three stories high with a basement. The floors were laid on heavy reinforced concrete beams, resting on pilasters 32 ins. square. They were built of concrete blocks, floated over with concrete mortar, thereby gaining a very good pilaster. In the basement were two big boilers for heating and power, put in before the floor was built over the basement. Fifteen days after we had the new concrete floor put in, by some mishap our cribbing took fire in the basement around these boilers, and in a space of about 30 ft. square there was about 2,000 ft. of cribbing lumber burned. It made a very hot fire and the concrete being just fifteen days old we were very much alarmed as to the outcome. The fire was finally put out with city water, the basement and the floor on top being drenched. We never saw anything come through the floor only a little steam. We left the building stand for about six months and the architect after a loading test of the floor, passed it as unhurt by the fire. This encouraged the owner so much that he did not place any insurance on the building at all. He reasoned that if it will stand that much fire with the concrete only fifteen days old, he need not fear. I believe that if we can get examples and tests of that kind to the insurance companies they will lower the rates. In our house construction, dwellings, we get a rate of 70 cts. for three years in Elkhart, Ind.

Mr. Perrot. MR. EMILE G. PERROT.—Replies to the letters of the Committee showed that a number of owners carried their own insurance, for the reason that they felt no need of insurance as their buildings were fireproof. In one case a company carried very inflammable stock and the rate on the building was very high, so instead of carrying insurance they simply eliminated it on account of the right rate, and thereby saved the annual premium.

MR. WALTER F. BALLINGER.—In considering the comparative insurance rates it should be borne in mind that there are other elements influencing the rates besides the character of the floor and wall construction of the building. The purpose for which the building is to be used, and the location have great weight. For instance a building which would have a comparatively low rate in an isolated section of a city might be required to pay a higher rate of insurance in a congested portion. The exposures, that is, other buildings which might get on fire and the fire be communicated into the fireproof building, are a consideration. The number of openings, or whether there are any openings that are unprotected through floors, and whether all openings are protected by walls and tin-lined doors and whether the exposures are protected by either tin-clad shutters or wireglass windows. Then the area of the building, that is the area of the floor space, affects the insurance rate, because a fire starting on one floor might burn out the contents of one story even though the buildings were fireproof. Then the number of stories in height would affect the rate, the upper stories making it more difficult for the fire department to operate, especially if the city water pressure is not sufficient to reach the upper stories. Then again, whether the building is protected by a fire extinguisher system or not. A building of thoroughly modern reinforced concrete construction and without any of these other advantages might be made to pay a higher rate of insurance than a building that is not fireproof and which has the other favorable features. Mr. Ballinger

To illustrate some of these points, I have in mind a machine wood-working factory which ordinarily carries a high rate of insurance. In this factory the older buildings were of joist construction, and before any fire equipment was installed the rate of insurance was 4 per cent. or $4.00 per $100.00. After the fire extinguisher equipment was put in and other improvements were made, these same old buildings only had to pay $1.31. Two reinforced concrete buildings have been added, the first of which pays $0.31 per $100.00 insurance, and in the basement or first story of that building is a power plant, boiler and engine. In the other reinforced concrete building containing dry kilns, which are usually considered hazardous, the rate is only $0.28.

REPORT OF COMMITTEE ON REINFORCED CONCRETE.

By Sanford E. Thompson, Chairman.

1. The recommendations in this report conform in general to the more complete report of the Joint Committee on Concrete and Reinforced Concrete representing the American Society of Civil Engineers, the American Society for Testing Materials, the American Railway Engineering and Maintenance of Way Association and the Association of American Portland Cement Manufacturers. The same unit stresses are suggested and the formulas are based on these unit stresses using methods of computation advised by the Joint Committee.

Uses.

2. Concrete, plain and reinforced, is recognized as an established material for construction. Because of its fire-resisting qualities, strength in compression, and relatively low cost, concrete is adapted not only to structures where stresses are principally compressive, such as foundations, dams, retaining walls and other walls, piers, abutments, short columns and arches; but with the use of metal reinforcement properly placed it is also available for a variety of structures and structural forms where both compression and tension exist, as in beams and slabs.

Resistance to External Agencies.

3. *Fire Resistance.*—Concrete is incombustible and resists the action of ordinary fires, so that it may be safely used for fireproofing purposes. The thickness of the protective coating required depends upon the probable duration of a fire which is likely to occur in a structure. For ordinary conditions it is recommended that the metal in girders and columns be protected by a minimum of 2 inches of concrete, that the metal in beams be protected by a minimum of 1½ inches of concrete, and that the

metal in floor slabs be protected by a minimum of 1 inch of concrete. In monolithic concrete columns the concrete to a depth of 1½ inches may be considered as a protective covering and not included in the effective section when computing the strength.

4. *Watertightness.*—When proportioned to attain greatest density, not leaner than one part cement to two parts fine aggregate, to four parts coarse aggregate, and mixed to a rather wet consistency, concrete is impervious under ordinary conditions. Long walls to resist water pressure must be effectively reinforced to prevent cracks due to temperature contraction or shrinkage, or must be waterproofed by asphaltic or similar preparation, or the length may be broken by vertical construction joints sealed by metal flashing.

5. *Corrosion of Metal Reinforcement.*—Steel embedded in good, dense concrete will not corrode under ordinary conditions whether located above or below fresh or sea water level. On the other hand, if concrete is porous, it may permit moisture to penetrate and corrode the metal.

6. *Sea Water.*—To best resist sea water, concrete must be proportioned to secure maximum density and mixed thoroughly to obtain impervious concrete.

7. *Acids.*—Concrete of first-class quality thoroughly hardened is affected appreciably only by strong acids which seriously injure other materials. A substance like manure because of the acid in its composition is injurious to green concrete, but after the concrete has thoroughly hardened it satisfactorily resists such action.

8. *Oils.*—When concrete is properly made and the surface carefully finished and hardened, it resists the action of such oils as petroleum and ordinary engine oils. Certain oils which contain fatty acids appear to produce injurious effects.

9. *Alkalies.*—In the arid regions alkaline ground water in some cases has been known to injure concrete and most other structural materials. For use under such conditions concrete should be especially rich, dense and impervious.

RESPONSIBILITY AND SUPERVISION.

10. The users of cement will recognize the great difference in both design and construction between plain concrete work such

as sidewalks, roads, foundations, heavy mass work, etc., and reinforced concrete structures. Plain concrete serves the requirements admirably for work where tensile stresses do not occur to any extent. In reinforced concrete structures steel must be added to the concrete to make a safe structure, and the proper sizes, dimensions and arrangement of concrete and steel to obtain safety, strength and durability require the knowledge and experience of the engineer. Many of our failures in reinforced concrete construction are the results of improper or inadequate design and many others are due to incompetent supervision.

11. It is, therefore, strongly recommended that all structures to be built of reinforced concrete shall be designed by experienced reinforced concrete engineers and that the drawings to be furnished to the builder shall show clearly and in detail the sizes and dimensions of all parts of the structure, the lengths of all steel reinforcement and its exact position with respect to the concrete members, and that these drawings shall be accompanied by specifications giving the quality of the materials to be used, the proportions of the concrete and the character of the workmanship.

12. It is also strongly recommended that the character of the supervision given to reinforced concrete structures be improved. Such supervision as is customary in the building trades is not sufficient to attain either successful or economical construction in reinforced concrete.

13. All reinforced concrete work should be under the constant direction of experienced reinforced concrete superintendents, —preferably men having a knowledge of engineering.

CEMENT.

14. Only Portland cement is suitable for reinforced concrete construction or for any construction that will be subject to shocks or vibrations or stresses other than direct compression.

15. The cement should meet the requirement of the Standard Specifications for cement as adopted by the American Society for Testing Materials.*

AGGREGATES.

16. *Fine Aggregates.*—Fine aggregate consists of sand, crushed stone or gravel screenings passing when dry a screen hav-

* Standard No. 1, National Association of Cement Users.

ing ¼ inch diameter holes or a screen having four meshes to the linear inch. It should be preferably of silicious material, clean, coarse, and free from vegetable loam and other deleterious matter.

17. It is impossible to positively determine the quality of a sand by inspection. Frequently a sand containing a very small percentage of silt may have its grains coated with organic or other matter so as to dangerously retard the setting of the concrete; consequently the testing of the sand is fully as important as the testing of the cement.

18. Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets should how a tensile strength of at least 70 per cent. of the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand. To avoid the removal of any coating on the grains which may affect the strength, bank sands should not be dried before being made into mortar but should contain natural moisture. The percentage of moisture may be determined upon a separate sample for correcting weight. From 10 to 40 per cent. more water may be required in mixing bank or artificial sands than for standard Ottawa sand to produce the same consistency.

19. The relative strength of mortars from different sands is largely affected by the size of the grains. A coarse sand gives a stronger mortar than a fine one, and generally a gradation of grains from fine to coarse is advantageous. If a sand is so fine that more than 10 per cent. of the total dry weight passes a No. 100 sieve, that is, a sieve having 100 meshes to the linear inch, or if more than 35 per cent. of the total dry weight passes a sieve having 50 meshes per linear inch, it should be rejected or used with a large excess of cement.

20. For the purpose of comparing the quality of different sands a test of the mechanical analysis or granulometric composition is recommended, although this should not be substituted for the strength test. The percentages of the total weight passing each sieve should be recorded. For this test the following sieves are recommended:*

* Sheet brass perforated with round holes passes the material more quickly than square holes. Round holes corresponding to sieves No. 8, 20 and 50 respectively are approximately 0.125, 0.050, 0.020 inch diameter.

0.250 inch diameter holes.*

No.	8	mesh,	holes	0.0955	inch	width	No. 23	wire.
No.	20.	"	"	0.0335	"	"	No. 28	"
No.	50	"	"	0.0110	"	"	No. 35	"
No.	100	"	"	0.0055	"	"	No. 40	"

21. The effect of mechanical analysis or granulometric composition upon the strength of mortar is illustrated in Appendix. By this table the relative strength of different sands may be approximately estimated.

22. *Coarse Aggregates.*—Coarse aggregate consists of inert material such as crushed stone, or gravel, which is retained on a screen having ¼ inch diameter holes. The particles should be clean, hard, durable, and free from all deleterious material. Aggregates containing soft, flat or elongated particles, should be excluded from important structures. A gradation of sizes of the particles is generally advantageous.

23. The maximum size of the coarse aggregate should be such that it will not separate from the mortar in laying and will not prevent the concrete fully surrounding the reinforcement or filling all parts of the forms. Where concrete is used in mass, the size of the coarse aggregate may be such as to pass a 3 inch ring. For reinforced concrete a size to pass a 1 inch ring or a smaller size may be used.

24. Cinder concrete is not suitable for reinforced concrete structures, and may be safely used only in mass for very light loads or for fireproofing.

25. Where cinder concrete is permissible, the cinders used as the coarse aggregate should be composed of hard, clean, vitreous clinker, free from sulphides, unburned coal, or ashes.

WATER.

26. The water used in mixing concrete should be free from oil, acid, strong alkalies, or vegetable matter.

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* A No. 4 sieve, having 4 meshes per linear inch, passes approximately the same size grains as a sieve with 0.25 in. diameter holes.

METAL REINFORCEMENT.

27. The Committee recommends that mild steel such as fills the specifications for structural steel of the American Railway Engineering and Maintenance of Way Association is a suitable material.

28. If steel of higher elastic limit is used, it must be of first-class quality and subjected to special tests even if used at the same working stress as mild steel. It should be required to pass the following test:

29. Test specimens for bending shall be bent cold under the following conditions without fracture on the outside of the bent portion:

Around twice their own diameter: 1 in. diameter 80 degrees; ¾ in. diameter 90 degrees; ½ in. diameter 110 degrees.

Around their own diameter: ¼ in. diameter 130 degrees; $^{3}/_{16}$ in. diameter 140 degrees; ⅛ in. diameter or less 180 degrees.

The reinforcement should be free from rust, scale, or coatings of any character which would tend to reduce or destroy the bond.

PROPORTIONS.

30. The materials to be used in concrete should be carefully selected, of uniform quality, and proportioned with a view to securing as nearly as possible a maximum density.

31. The unit of measure should be the barrel, which should be taken as containing 3.8 cubic feet. Four bags containing 94 pounds of cement each should be considered the equivalent of one barrel. Fine and coarse aggregate should be measured separately as loosely thrown into the measuring receptacle.

32. If the coarse aggregate contains sand or other fine material, that which passes a sieve with ¼ inch round holes should be considered as sand in measuring proportions. In general, the concrete on the work should contain enough and only enough mortar to cover all particles of stone and fill the voids without an appreciable excess of mortar.

33. The proportions of cement to sand and stone should be chosen after a very careful study of the local conditions and the available materials. For small and unimportant structures the following list is presented to be used as a rough guide to the

selection of proportions for different classes of work. The relative proportions of fine to coarse aggregate may be varied to suit the materials:

(*a*) A *Rich Mixture* for columns and other structural parts subjected to high stresses or requiring exceptional water-tightness: Proportions 1 : 1½ : 3; that is, one barrel (4 bags) packed Portland cement to 1½ barrels (5.7 cubic feet) loose sand to 3 barrels (11.4 cubic feet) loose gravel or broken stone.

(*b*) A *Standard Mixture* for reinforced floors, beams and columns, for arches, for reinforced engine or machine foundations subject to vibrations, for tanks, sewers, conduits, and other water-tight work: Proportions 1 : 2 : 4; that is, one barrel (4 bags) packed Portland cement to 2 barrels (7.6 cu. ft.) loose sand to 4 barrels (15.2 cu. ft.) loose gravel or broken stone.

(*c*) A *Medium Mixture* for ordinary machine foundations, retaining walls, abutments, piers, thin foundation walls, building walls, ordinary floors, sidewalks, and sewers with heavy walls: Proportions 1 : 2½ : 5; that is, one barrel (4 bags) packed Portland cement to 2½ barrels (9.5 cu. ft.) loose sand to 5 barrels (19 cu. ft.) loose gravel or broken stone.

(*d*) A *Lean Mixture* for unimportant work in masses, for heavy walls, for large foundations supporting a stationary load, and for backing for stone masonry: Proportions 1 : 3 : 6; that is, one barrel (4 bags) packed Portland cement to 3 barrels (11.4 cu. ft.) loose sand to 6 barrels (22.8 cu. ft.) loose gravel or broken stone.

MIXING OF CONCRETE.

34. Methods should be devised to always make positive the proper proportioning and therefore the accurate measuring of the concrete materials, including water. Accurate measurements are of the greatest importance.

35. The concrete materials should be mixed until the cement is uniformly distributed throughout the mass and the concrete

therefore uniform in color and homogeneous. Sufficient water must be added during the mixing to produce a concrete that will flow when agitated, but not so wet as to permit a separation of the materials in transferring from mixer to the work. Mixing by machine should always be preferred, since the most thorough and uniform consistency can be thus obtained.

36. A type of mixer should be used which will insure thorough and accurate proportioning of the materials throughout the mass.

37. Where hand mixing is necessary the mixing should be done on a water-tight platform and special precautions taken to turn the materials until they are homogeneous in appearance and color. Concrete that has started to set or has been out of the mixer more than thirty minutes should not be used. Re-tempering of either mortar or concrete which has partially hardened should not be permitted.

38. Concrete for reinforced concrete structures should not be mixed or deposited at a freezing temperature, unless special precautions are taken to avoid the use of materials containing frost and to provide means for preventing the concrete from freezing after being placed in position and until it has thoroughly hardened.

PLACING CONCRETE.

39. Concrete must be placed in the work immediately after mixing and deposited and rammed or agitated by suitable tools in such a manner as to produce thoroughly compact concrete of maximum density. No concrete should be placed until the reinforcing steel has been placed and firmly secured by wiring or other methods to prevent displacement. Concrete should be frequently wet for several days to prevent too rapid drying out.

40. Concrete should not be placed in water, unless unavoidable. Where concrete must be placed under water, unusual care must be taken to prevent the cement from being floated away. This usually can be accomplished in still water by placing the concrete through a large pipe or tube, or in large work by means of a bottom dump concrete basket. Before placing concrete, all shavings and debris of every nature must be removed and the concrete surface thoroughly cleaned and drenched with water.

FORMS.

41. Forms should be substantially built and secured to prevent movement or deflection during concreting, and tight to prevent leakage of mortar.

42. Before the removal of forms, the concrete should be carefully inspected and its strength ascertained. Much care should be given to this portion of the work, which is fraught with danger under incompetent direction. No exact time for the removal of forms can be safely prescribed because of the varying character of the work, the variations in the setting of different cements and the influence of atmospheric conditions.

JOINTS.

43. Temperature changes and shrinkage during setting necessitate joints at frequent intervals or else effective reinforcement, depending upon the range in temperature and the design of the structure.

44. In massive work, such as retaining walls, abutments, etc., built without reinforcement, joints should be provided approximately every 30 to 50 feet throughout the length of the structure.

45. Girders should never be constructed over freshly formed columns without allowing a period of at least two hours to elapse to permit settlement in the columns. Before resuming work the top of the column should be thoroughly cleansed of foreign matter and laitance.

46. To obtain tight joints between new and old concrete the old surface should be roughened, thoroughly cleaned of all foreign material and laitance or scum, drenched, and slushed with neat cement or a mortar not leaner than one part Portland cement to two parts fine aggregate.

47. Joints in reinforced concrete should be avoided when possible by casting the entire structure at one operation. In building construction, joints may be made in the columns flush with the lower side of the girders, and joints in members of a floor system in general should be made at or near the center of the span. In all cases joints should be at right angles to the surfaces.

DESIGN OF REINFORCED CONCRETE.

48. By the use of metal reinforcement to resist the principal tensile stresses, concrete becomes available for general use in a great variety of structures and structural forms. This combination of concrete and steel is particularly advantageous in the beam where both compression and tension exist; it is also advantageous in the column where the main stresses are compressive, but where cross bending may exist. The theory of design will therefore relate mainly to the analysis of beams and columns.

49. *Loads.*—The loads or forces to be resisted consist of:

(*a*) The *dead load,* which includes the weight of the structure and fixed loads and forces.

(*b*) The *live load* or the loads and forces which are variable. The dynamic effect of the live load will often require consideration. Any allowance for the dynamic effect is preferably taken into account by adding the desired amount to the live load or to the live load stresses. The working stresses hereinafter recommended are intended to apply to the equivalent static stresses so determined.

50. In the case of high buildings the live load on columns may be reduced in accordance with the usual practice.

51. *Lengths of Beams and Columns.*—The span length for beams and slabs shall be taken as the distance from center to center of supports, but shall not be taken to exceed the clear span plus the depth of beam or slab. Brackets shall not be considered as reducing the clear span in the sense here intended.

52. The length of columns shall be taken as the maximum unsupported length.

WORKING STRESSES.

53. The working stresses given below are as recommended by the Joint Committee on Concrete and Reinforced Concrete for limiting values.

54. *General Assumptions.*—The following working stresses are recommended for static loads. Proper allowances for vibration and impact are to be added to live loads where necessary to

produce an equivalent static load before applying the unit stresses in proportioning parts.

55. In selecting the permissible working stress to be allowed on concrete, we should be guided by the working stresses usually allowed for other materials of construction, so that all structures of the same class but composed of different materials may have approximately the same degree of safety.

56. The stresses for concrete are proposed for concrete composed of one part Portland cement and six parts aggregate, capable of developing an average compressive strength of 2,000 pounds per square inch at twenty-eight days, when tested in cylinders 8 inches in diameter and 16 inches long, under laboratory conditions of manufacture and storage, using the same consistency as is used in the field. In considering the factors recommended with relation to this strength, it is to be borne in mind that the strength at twenty-eight days is by no means the ultimate which will be developed at a longer period, and therefore they do not correspond with the real factor of safety. On concretes, in which the material of the aggregate is inferior, all stresses should be proportionally reduced, and similar reduction should be made when leaner mixes are to be employed. On the other hand, if, with the best quality of aggregates, the richness is increased, an increase may be made in all working stresses proportional to the increase in compressive strength at twenty-eight days, but this increase shall not exceed 25 per cent.

57. *Bearing.**—For compression on surface of concrete larger than loaded area,

> 32.5 per cent. of compressive strength at twenty-eight days, or 650 pounds per square inch on 2,000 pound concrete.

58. *Plain Columns.*—Plain columns or piers whose length does not exceed twelve diameters,

> 22½ per cent. of compressive strength at twenty-eight days, or 450 pounds per square inch on 2,000 pound concrete.

59. *Reinforced Columns.*—(See paragraphs 96 to 104 on Columns.)

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* For beams and girders built into pockets in concrete walls, the lower Compressive Stress of 450 pounds per square inch should not be exceeded.

60. *Compression in Extreme Fiber.*—For extreme fiber stress of beams calculated for constant modulus of elasticity,

32.5 per cent. of the compressive strength at twenty-eight days, or 650 pounds per square inch for 2,000 pound concrete.

61. Adjacent to the support of continuous beams, stresses 15 per cent. greater may be allowed.

62. *Shear.*—Pure shearing stresses uncombined with compression or tension,

6 per cent. of compressive strength at twenty-eight days, or 120 pounds per square inch for 2,000 pound concrete.

63. *Diagonal Tension.*—In beams where diagonal tension is taken by concrete, the vertical shearing stresses should not exceed

2 per cent. of compressive strength at twenty-eight days, or 40 pounds per square inch for 2,000 pound concrete.

(See also paragraph 88, Shear and Diagonal Tension.)

64. *Bond for Plain Bars.*—Bonding stress between concrete and plain reinforcing bars,

4 per cent. of compressive strength at twenty-eight days, or 80 pounds per square inch for 2,000 pound concrete.

Bond for Drawn Wire.

2 per cent., or 40 pounds on 2,000 pound concrete.

65. *Bond for Deformed Bars.**—Bonding stress between concrete and deformed bars may be assumed to vary with the character of the bar from

5 per cent. to 7½ per cent. of the compressive strength of the concrete at 28 days or from

100 to 150 pounds per square inch for 2,000 pound concrete.

66. *Reinforcement.*—The tensile stress in steel should not exceed 16,000 pounds per square inch. The compressive stress in reinforcing steel should not exceed 16,000 pounds per square inch, or fifteen times the working compressive stress in the concrete.

* No recommendation for deformed bars is given in the report of the Joint Committee

67. *Modulus of Elasticity.*—It is recommended that in all computations the modulus be assumed as $^1/_{15}$ that of steel; that is, that a ratio of fifteen be employed.

STANDARD NOTATION.

68. The following notation is recommended by the Joint Committee:

M = moment of resistance, or bending moment in general, in inch pounds.
A = steel area in square inches.
f_s = tensile unit stress in steel.
f_c = compressive unit stress in concrete.
b = breadth of beam (in a T-beam, breadth of flange) in inches.
b′ = breadth of web or stem in a T-beam in inches.
d = depth of beam from compressive surface to center of steel in inches.
t = thickness of flange in inches.
jd = distance between center of compression and center of steel in inches.
k = ratio of depth of neutral-axis to effective depth, d.
V = total shear in pounds.
v = shearing unit stress in pounds per square inch.
u = bond stress per unit area of bar.
o = circumference or perimeter of bar in inches.
Σo = sum of the perimeters of all bars in inches.
s = distance apart of the stirrups.

RECTANGULAR BEAMS.

69. In a rectangular beam neither the allowable working compressive stress in the concrete nor the allowable tension in the steel should be exceeded. These stresses in practice may be determined by the following formulas:

$$f_s = \frac{M}{.87\ Ad} \qquad (1)$$

$$f_c = \frac{2M}{jkbd^2} \qquad (2)$$

For 0.8 per cent. steel, which gives the stresses already suggested for 2,000 pound concrete, $j = 0.88$, and $k = 0.38$, so that the value of f_c becomes approximately $\frac{6M}{bd^2}$.

70. For a design based on working stresses recommended in paragraphs 60, 66 and 67, *i. e.*, compression in concrete 650 pounds per square inch, tension in steel 16,000 pounds per square inch and ratio of elasticity of 15, the depth of the beam is

$$d = \frac{1}{10}\sqrt{\frac{M}{b}} \qquad (3)$$

In order to have the specified tension and compression so that the above formula will apply, the percentage of steel must be 0.8 per cent. The area of cross section of tensile steel reinforcement is therefore

$$A = 0.008bd \qquad (4)$$

In using these formulas, the maximum bending moment, M, is computed in inch-pounds, the breadth b is assumed and the depth to steel, d, is found from the formula. The full depth is obtained by adding to d a thickness of concrete required to imbed and protect the steel. The area of steel is then obtained from formula (4). Shear and bond are considered in succeeding paragraphs.

T-BEAMS.

71. Where adequate bond between slab and web of beam is provided, the slab may be considered as an integral part of the beam, and its effective width may be determined by the following rules:

(*a*) It shall not exceed one-fourth of the span length of the beam;

(*b*) Its overhanging width on either side of the web shall not exceed four times the thickness of the slab.

72. Following the above requirements and where ample provision has been made for shear, the formulas just given for rectangular beams may be applied without material error so long as the depth, d, is not greater than 5 times the thickness of the slab.*

* Beyond these limits the more exact formulas given in the report of the Joint Committee should be adopted.

73. In using the rectangular beam formulas the width of the slab as above specified is taken as the breadth of beam, b, in computing compression, but in the formulas for shear and bond the width of the stem or web is used.

74. The area of steel may be obtained (when the depth of beam, d, does not exceed 5 times the thickness of the slab) by the formula

$$A = \frac{M}{.87 f_s d} \tag{5}$$

For 16,000 pound stress in steel this formula becomes

$$A = \frac{M}{14{,}000\, d} \tag{6}$$

75. The width of the stem or web of the T is governed by the proper embedding of the rods and the area required to resist diagonal tension, as indicated in paragraphs which follow. Web reinforcement is considered in paragraphs 86 to 95.

FLOOR SLABS.

76. Floor slabs should be designed and reinforced as continuous over the supports. If the length of the slab exceeds 1.5 times its width the entire load should be carried by transverse reinforcement. Square slabs may well be reinforced in both directions using one-half the computed reinforcement in each direction.

77. The loads carried to beams by slabs which are reinforced in two directions will not be uniformly distributed to the supporting beam but may be assumed to vary in accordance with the ordinates of a triangle. The moments in the beams should be calculated accordingly.

CONTINUOUS BEAMS AND SLABS.

78. In computing the positive and negative moments in beams and slabs continuous over several supports, due to uniformly distributed loads, the following rules are recommended by the Joint Committee:

(*a*) That for floor slabs the bending moments at center and at support be taken at $\frac{wl^2}{12}$ for both dead and live

loads, where w represents the load per lineal foot and l the span length.*

(*b*) That for beams the bending moment at center and at support for interior spans be taken at $\frac{wl^2}{12}$, and for end spans it be taken at $\frac{wl^2}{10}$ for center and adjoining support, for both dead and live loads.*

79. In the case of beams and slabs continuous for two spans only, or of spans of unusual length, more exact calculations should be made. Special consideration is also required in the case of concentrated loads.

BONDING STRENGTH AND SPACING OF BARS.

80. In direct pull or direct compression a bar must be embedded a length sufficient to give a working strength in bond equivalent to the working strength of the steel in tension or compression. For 2,000 pounds concrete, in which 80 pounds per square inch is permitted in bond, and a working strength of 16,000 pounds per square inch in the steel, plain round bars thus require an embedded length of fifty diameters.

81. The bond stress in the horizontal bars in a beam may be represented by the formula

$$u = \frac{V}{jd\Sigma o} \qquad (7)$$

82. With the unit bond of 80 pounds per square inch (assuming $jd = \frac{7}{8}\ d$), the total circumference of tension rods at any section of the beam should be at least

$$\Sigma o = \frac{V}{70\,d} \qquad (8)$$

83. For T-beams b′ is substituted for b and jd may be taken as approximately the distance from center of slab to steel.

84. Where high bond resistance is required, the deformed bar is a suitable means of supplying the necessary strength. Adequate bond strength throughout the length of a bar is preferable to end anchorage, but such anchorage may properly be used

* A still more conservative plan is to use $\frac{wl^2}{10}$ at the middle of all spans.

in special cases. Anchorage furnished by short bends at a right angle is less effective than hooks consisting of turns through 180 degrees.

85. The lateral spacing of bars should not be less than two and one-half diameters, center to center, nor should the distance from the side of the beam to the center of the nearest bar be less than two diameters. The clear spacing between two layers of bars should be not less than ½ inch.

SHEAR AND DIAGONAL TENSION.

86. Calculations for web resistance shall be made on the basis of maximum shearing stress as determined by the formulas hereinafter given. When the maximum shearing stresses exceed the value allowed for the concrete alone, web reinforcement must be provided to carry the diagonal tensile stresses involved. This web reinforcement may consist of bent bars, or inclined or vertical members attached to or looped about the horizontal reinforcement. When inclined members are used, the connection to the horizontal reinforcement shall be such as to insure against slip.

87. Experiments bearing on the design of details of web reinforcement are not yet complete enough to allow more than general and tentative recommendations to be made. It is well established, however, that a very moderate amount of reinforcement, such as is furnished by a few bars bent up at small inclination, increases the strength of a beam against failure by diagonal tension to a considerable degree; and that a sufficient amount of web reinforcement can readily be provided to increase the shearing resistance to a value from three or more times that found when the bars are all horizontal and no web reinforcement is used.

88. The Joint Committee recommend the following allowable values for maximum shearing stresses for concrete whose crushing strength is 2,000 pounds at twenty-eight days:

(*a*) For rectangular beams with horizontal bars only, web reinforcement is necessary when $\frac{V}{bjd}$ is greater than 40, or (assuming distance between centers of tension and compression to be ⅞ d) when $\frac{V}{bd}$ is greater than 35.

(*b*) For rectangular beams in which a part of the horizontal reinforcement is used in the form of bent-up bars arranged with due respect to shearing stresses, a higher value may be allowed, but not to exceed 60 pounds per square inch. In this case (assuming $jd = \frac{7}{8}\ d$) stirrups will be required when $\frac{V}{bd}$ is greater than 52.

(*c*) In any case, no matter how thoroughly reinforced for diagonal tension, the total shear should not exceed 120 pounds per square inch, that is (assuming $jd = \frac{7}{8}\ d$) bd must never be less than $\frac{V}{105}$.

89. For T-beams the same rules apply except that only the web of the beam is effective; hence, b′ must be substituted for b.

90. In the calculation of web reinforcement to provide a strength of 120 pounds per square inch, the concrete may be counted upon as carrying one-third of the shear, or for 2,000 pound concrete 40 pounds per square inch. The remainder may be provided for by means of metal reinforcement consisting of bent bars or stirrups, but preferably both. The area of a stirrup, acting in tension, must be proportioned to the force equal to the whole horizontal shear produced between the two adjacent stirrups less the amount to be carried by the concrete. This total horizontal shear may be found by multiplying the distance between stirrups by the average horizontal unit shear, which is equal to the vertical unit shear, and is represented by the expression $\frac{V}{jd}$.

91. In accordance with this method the stress in a vertical stirrup will be equal to $\frac{Vs}{jd}$ and in a stirrup or bent rod at 45 degrees it will equal $0.7\ \frac{Vs}{jd}$, in which s = horizontal spacing, that is, the distance apart, of stirrups or bent rods.

92. In these formulas V is taken as the proportion of total shear assumed as carried by the reinforcement.

93. The longitudinal spacing of stirrups shall not exceed three-fourths the depth of the beam in the portion of the beam where the shearing stresses exceed the allowable shearing value of the concrete.

94. It is important that adequate bond strength be provided to fully develop the assumed strength of all shear reinforcement.

95. Inasmuch as small deformation in the horizontal reinforcement tends to prevent the formation of diagonal cracks, a beam will be strengthened against diagonal tension failure by so arranging the horizontal reinforcement that the unit stresses at points of large shear shall be relatively low.

COLUMNS.

96. It is recommended that the ratio of unsupported length of column to its least width be limited to fifteen.

97. The effective area of the column shall be taken as the area within the protective covering, as defined in paragraph 3. Or in the case of hooped columns or columns reinforced with structural shapes it shall be taken as the area within the hooping or structural shapes.

98. Columns may be reinforced by means of longitudinal bars, by bands or hoops, by bands or hoops together with longitudinal bars or by means of structural forms which in themselves are sufficiently rigid to act as columns. The general effect of bands or hoops is greatly to increase the "toughness" of the column and its ultimate strength, but hooping has little effect upon its behavior within the limit of elasticity. It thus renders the concrete a safer and more reliable material and should permit the use of a somewhat higher working stress. The beneficial effects of "toughening" are inadequately provided by a moderate amount of hooping, a larger amount serving mainly to increase the ultimate strength and the possible deformation before ultimate failure.

99. The following recommendations are made for the relative working stresses in the concrete for the several types of columns:

(*a*) Columns with longitudinal reinforcement only, the unit stress recommended in paragraph 58.

(*b*) Columns with reinforcement of bands or hoops, as specified below, stresses 20 per cent. higher than given for (*a*).

(*c*) Columns reinforced with not less than 1 per cent. and not more than 4 per cent. of longitudinal bars and with bands or hoops, stresses 45 per cent. higher than given for (*a*).

(*d*) Columns reinforced with structural steel column units which thoroughly encase the concrete core, stresses 45 per cent. higher than given for (*a*).

100. In all cases, in addition to the stress borne by the concrete given above, longitudinal reinforcement is assumed to carry its proportion of stress in accordance with the ratio of its elasticity to concrete. For example, with a working stress in concrete of 450 pounds per square inch, the longitudinal reinforcement may be assumed to carry $15 \times 450 = 6{,}750$ pounds per square inch.

101. The hoops or bands are not to be counted upon directly as adding to the strength of the column.

102. Bars composing longitudinal reinforcement shall be straight and shall have sufficient lateral support to be securely held in place until the concrete is set.

103. Where bands or hoops are used, the total amount of such reinforcement shall be not less than 1 per cent. of the volume of the column enclosed. The clear spacing of such bands or hoops shall be not greater than one-fourth the diameter of the enclosed column. Adequate means must be provided to hold bands or hoops in place so as to form a column, the core of which shall be straight and well centered.

104. Bending stresses due to eccentric loads must be provided for by increasing the section until the maximum stress does not exceed the values above specified.

SPLICING OF BARS.

105. Wherever in tension reinforcement it is necessary to splice the reinforcing bars, the length of lap shall be determined on the basis of the safe bond stress and the stress in the bar at the point of splice; or a connection shall be made between the bars of sufficient strength to carry the stress. Splices at points of maximum stress should be avoided. In columns large bars should be properly butted and spliced; small bars may

be treated as indicated for tension reinforcement or their stress may be taken off by being embedded in large masses of concrete. At foundations, bearing plates should be provided for large bars or structural forms.

REINFORCING FOR SHRINKAGE AND TEMPERATURE STRESSES.

106. Where large areas of concrete are exposed to atmospheric conditions, the changes of form due to shrinkage (resulting from hardening) and to action of temperature are such that large cracks will occur in the mass, unless precautions are taken to so distribute the stresses as either to prevent the cracks altogether or to render them very small. The size of the cracks will be directly proportional to the diameter of the reinforcing bars and inversely proportional to the percentage of reinforcement and also to its bond resistance per unit of surface area. To be most effective therefore reinforcement should be placed near the exposed surface and well distributed, and a form in reinforcement used which will develop a high bond resistance.

APPENDIX.

TESTS BY NEW YORK BOARD OF WATER SUPPLY OF 1:3 MORTAR MADE WITH SANDS OF DIFFERENT MECHANICAL ANALYSIS.

Percentages Passing Sieves.				Tensile Test.		Compression Test.	
No. 4	No. 8.	No. 50.	No. 100.	7 days.	90 days.	7 days.	90 days.
100	70	12	5	213	613	2690	5640
100	86	21	6	263	412	1915	4660
100	99	26	2	177	325	905	2170
100	97	28	6	178	282	1070	1500
100	94	44	12	139	228	965	1130
100	100	52	14	122	170	275	810
100	100	94	48	80	149	330	490

DISCUSSION.

Mr. H. S. Doyle (by letter).—As a discussion of the Report of the Committee on Reinforced Concrete I would like to make the following suggestions: **Mr. Doyle.**

Metal Reinforcement.—I would add to Paragraph 27 that under no conditions should re-rolled steel be used in reinforcing concrete. While I understand of course that the specifications of the American Railway Engineering and Maintenance of Way Association cover this, I think that either their specifications should be included here or that this should be specifically mentioned. Also that all metal reinforcement may be made from either new Bessemer or Basic Steel billets.

Proportions.—Paragraph 33 (*b*). I believe that the first line should read "A standard mixture for reinforced walls, floors, columns, etc." I think the mixture should be equally as good for walls as for floors, beams, columns, etc. This should come under the 1-2-4 mix.

Bond for Plain Bars.—Paragraph 64. From my personal experience and knowledge of wire, I do not believe that it is fair to allow for bars 4 per cent. of the compressive strength at 28 days, or 80 lbs. per sq. in. for 2,000 lbs. concrete, and for wire 2 per cent. or 40 lbs. per sq. in. I think that galvanized wire and rods should not be on identically the same basis, but I do believe that 2 per cent. or 40 lbs. is fair where galvanized wire is needed, and that this distinction be made.

Paragraph 66. I believe that the fibre stress on steel should not exceed 16,000 lbs. on a mild or commercial steel hot rolled, but on cold drawn wire or cold rolled steel, I think a higher maximum fibre stress should be allowed. I would suggest the following in lieu of Paragraph 66:

Reinforcement.—The tensile strength in steel should not exceed 16,000 lbs. per sq. in. for mild steel hot rolled from new billets, and should not exceed 20,000 lbs. per sq. in. for drawn wire, and in no case should the stress in steel exceed one-half of the elastic limit for hot rolled steel, or one-third of the elastic limit for cold drawn steel.

Mr. Doyle. The above I believe are all the suggestions I have to make at the present time.

Mr. Skinner. MR. THEODORE H. SKINNER (by letter).—The following comments are submitted with the hope that they may be of service:

Metal Reinforcement.—Referring to the bending tests proposed for steel specimens, Paragraph 28, I think they would be more definite and cover the ground better if reading as follows:

28. If steel of higher elastic limit than provided for by Paragraph 27 is used, it must be of first-class quality, and must be submitted to the following tests even if used at the same working stress as mild steel, and specimens must be bent cold around a pin twice their own diameter without any sign of cracking on the outside of the bend—

(*a*) If 1 in. or greater in diameter to angle of 80 degrees.
If ¾ " " " " " " " " 90 "
If ½ " " " " " " " " 110 "

(*b*) Smaller specimens should be bent cold around pins of their own diameter—

If ¼ in. in diameter to angle of 130 degrees.
If $^{5}/_{16}$ " " " " " " 140 "
If ⅛ " " " " " " 180 "

Mixing.—Paragraph 36 should be changed to read "A mixer should be used, etc."

Joints.—Paragraph 45. My observation leads me to believe that two hours is not sufficient time for the concrete in the column to have reached equilibrium, and that if we are making a recommendation embodying good practice, twelve hours should be the minimum period. I have seen large cracks between the columns and girders as a result of pouring the girder concrete too soon.

Paragraph 47. The word "structure" should read member, as it is impossible to continue the operation on the whole structure without interruption, but it is possible under general conditions to cast a member (column, girder or section of wall) complete at one pouring, and it is often necessary in large work to introduce definite joints for expansion and contraction. In the matter of joints in members of the floor system, it is not made clear whether the joining or lapping should be in a direction parallel to the girder, or at right angles thereto, but it does state that "in all cases joints should be at right angles to the surfaces."

Mr. Skinner.

It seems to me that this would be more definite if it specified that joints in slabs and beams should be as nearly vertical as possible, and long scarfs or inclined joints should be avoided.

Bearing.—Paragraph 57. The statement "For compression on surface of concrete larger than loaded area" is not clear. From the foot-note it seems that for the bearing of the beam in the wall, compression at the bearing should not exceed the minimum compressive stress of 450 lbs. per sq. in. This paragraph should be made so that it could be understood.

Bond for Plain Bars.—Paragraph 64. My experience has been that there is no bond between straight drawn wire and concrete that can be figured or depended upon, and I should rather see the paragraph omitted. Of course, if the wire is sufficiently deformed by corrugation or by welded anchors, the strength of the wire may be developed in combination with the concrete, but it is due to some form of mechanical bond rather than to an adhesive bond.

Reinforcement.—Paragraph 66 does not mention high carbon steel or wire, whereas the "Proposed Building Regulations" allow 20,000 lbs. per sq. in. for high carbon steel with approved mechanical bond, and many good authorities are willing to allow as high as 24,000 lbs. per sq. in. tensile stress in cold drawn wire, provided a proper mechanical bond is effected between the wire and the concrete. On this point I am of the opinion that where the steel wire has an ultimate strength of from 90,000 to 120,000 lbs. per sq. in., and the elastic limit is proportionately high, that it is perfectly safe to figure a higher stress per sq. in. on wire than it is on rods. In my practice and as a result of two years' experimental work, I am satisfied that it is safe to figure stresses in deformed wire up to one-half of the actual elastic limit of the wire being used, and would be glad to see the recommendation changed to allow stresses in steel wire, provided proper mechanical bond with the concrete is accomplished, as high as 30,000 lbs. per sq. in., but should be satisfied for the present to have the specifications allow a figured working stress of 24,000 lbs. per sq. in. for use in slab work.

Floor Slabs.—Paragraph 77 does not state the facts exactly, or at least completely. In a square panel a uniform load over

Mr. Skinner. the entire panel, or a concentrated load would be distributed uniformly to the surrounding beams, while in a rectangular panel the proportion of the load which each beam would carry would vary with the dimensions of the panel, if the load were uniformly distributed, and would vary again, depending on the location of the load, if it were a concentrated load. Some additional indication of how to determine the ordinate of the triangle mentioned should be added.

Columns.—Paragraph 102 states that bars composing longitudinal reinforcement should be straight. Is this supposed to mean that twisted or other deformed bars should not be used? If this is the intention I think it should be stated in the form of a recommendation that deformed bars should not be used for vertical column reinforcement. I believe that this is an important matter, and personally am of the opinion that any deformation of the vertical bar is a detriment to the column.

Mr. McCullough. MR. ERNEST MCCOLLOUGH (by letter).—*Waterproofing.*—The recommendation of asphaltic or similar preparations for waterproofing seems like advertising, and this reference should be omitted. In my opinion the Committee should say that the watertightness of concrete is as yet a mooted question and that until something better and cheaper is discovered, a mixture richer than 1-2-4 should be used. This report is bound to be considered as more or less authoritative and a great many of us have found that asphaltic preparations are not of such great utility as this report would seem to indicate. For general recommendations it is unfortunate that reference was made to waterproofing preparations that are not incorporated with concrete. Such preparations are only of limited value and in particular instances.

Sea Water.—Paragraph 6. In referring to sea water why does not the Committee state that the only cement thus far seemingly affected is that containing a high percentage of lime? It is not enough to secure impervious concrete, but care should be taken to see that the cement is entirely free from raw material and contains the minimum percentage of lime.

Alkalies.—Paragraph 9. The same criticism as of Paragraph 6 applies herein. Referring to concrete mixed for use in regions where alkali may be present and might endanger the

concrete, the further caution should be given that in alkali countries the stone, sand and water should be analyzed by a competent chemist before use. The writer practised for a great many years in the alkali regions of the West and has there mixed concrete. Mr. McCullough.

Responsibility and Supervision.—Paragraphs 10-13 inclusive miss their object by being too long-winded and diffuse. Paragraph 13 should replace Paragraph 10, and 12 should replace 11. The present Paragraphs 10 and 11 by being omitted would lead to the two others being read and given proper attention.

Cement.—Paragraph 14. The reasons given here for the employment of Portland cement are not the real reasons for its use to the exclusion of other hydraulic cements. That is, one would gather from reading this section that other cements are not good in situations where shocks and vibrations exist, yet in other parts of the report emphasis is placed on the fact that in reinforced concrete only compressive stresses are to be figured on as being taken care of by the concrete. The report should have gone somewhat at length into all the reasons why Portland cement is the only cement to use in reinforced structures and not content itself with making a bald statement.

Fine Aggregates.—Paragraphs 16-21, inclusive. In common with a great number of men who have to actually mix and use concrete on work and who are compelled to use what sand they can secure from local dealers, I cannot help but feel aggrieved that so much space is given to the question of proportioning and discussion of sand grains. There is now too much such discussion and I believe it is only serving to make many practical men flee from the sight of reports in which highly theoretical questions are given prominence. This report is intended by the Association to be a guide for the men who need instruction and who do not read and study text-books—the practically trained men in the country who look to the Association as a parliament of experienced men. Generally the stresses allowed are such that extreme nicety in the selection and assortment of sand does not pay. The man on the job has to rush the work through and mix the materials in the proportions mentioned in the specifications. A laboratory and arrangement of sieves cannot be carried on to

Mr. McCullough. the job and be kept in operation. There is too much rush and hurry and if the constructor obtains ordinary sand that is clean he has much to be thankful for. The effect of granulometric composition upon the strength of mortar is well known to all users and this much of the report might well have been reserved for an appendix, if inserted at all.

Coarse Aggregates.—Paragraph 23. The Committee states that for reinforced concrete a size of stone to pass a one-inch ring or a smaller size may be used. Why the word "may"? It is not always best to have stone running under one inch in size. In some cases larger stone may be used and my rule is that the larger size should not exceed in any dimension one-fourth of the thickness of the wall or slab or column and should not in any case exceed the spacing between the principal reinforcement.

Paragraph 24. Cinder concrete is greatly used and the dangers of its use should be fully pointed out in order that men who do use it may be prepared to use it properly. I believe that owing to its porosity the covering of cinder concrete should be thicker around the steel than the covering of stone concrete. Also that all reinforcing steel used in cinder concrete should be dipped in cement paste before the concrete is deposited.

Metal Reinforcement.—Paragraphs 27-29 inclusive. These paragraphs are not complete when we consider the vast amount of advertising that is being done by companies selling steel other than that recommended by the Committee. In paragraph 28 reference is made to steel having a higher elastic limit, but nothing is said about the manner in which this higher elastic limit is secured. If the high elastic limit is due to a large amount of carbon or materials tending to make the steel brittle then some specifications should be submitted to show just what such a steel should be. If the higher elastic limit is secured by working a medium steel then the difference in percentage between the elastic limit and the ultimate strength should be fixed. Give every steel a chance in language that will permit the half-instructed man to know that something is being said about every steel he sees advertised. We all know that if we did not believe there were a great many half-instructed men in the world there would be no occasions for reports such as this, therefore they should not be vaguely worded.

Mr. McCullough.

Proportions.—Paragraph 31. This report is apparently made to satisfy certain engineers. It does not consider the men who outnumber the engineers a thousand to one, namely, the men who are using concrete in the hot sun and not in the pleasant office or in the laboratory. To the men in the sun and the rain a bag of cement is a cubic foot because it is convenient to so consider it. Therefore, why not recognize the fact in this report that is intended to go out to the field workers? In my opinion the report should come out openly and say that one bag of cement weighing not less than ninety-five pounds gross is to be considered as one cubic foot. The contractor says a bag is a foot and that settles it. The cement salesman is the man who gives him that information and I have heard it given to the men by salesmen of many companies. It is an easy unit and avoids fractions. Contractors and their foremen dislike fractions and like even figures. Let us get in harmony with them.

Paragraph 33. Everything is fractional and the barrel is given as a unit in all cases when one seldom sees a barrel nowadays on a job. The bag is replacing the barrel for cement and there are many different units for barrels so that unless we tell exactly the size of the barrel we mean then we are pretty far away from what we want to get. This is shown by the explanation in cubic feet. It would be so much more sensible to do just what the contractor does; that is count a bag of cement as one cubic foot and make measuring boxes to contain a certain definite number of cubic feet of sand and stone and leave out the tenths and inches. The barrel as a unit is decidedly out of date when one has to explain in parentheses just how many cubic feet is meant.

Reinforcement.—Paragraph 66. This section should be changed to read that the tensile stress in steel should not exceed one-third the elastic limit and that the stress should not exceed with any steel a maximum of 16,000 lbs. per sq. in. Inasmuch as a great many companies are using stresses of 20,000 lbs. this section should contain a clause relating to elongation under stress. In this clause a compressive stress of 16,000 lbs. is permitted. Here we have a section going to the extreme of caution in the first clause and going as far the other way in the last clause.

Mr. McCullough. What justification have the members of the Committee to offer for such a compressive stress, seeing that the reinforcement is commonly in long slender bars?

T-Beams.—Paragraph 71. It should be impressed upon the reader that the slab and beam can only be considered as acting together when they are poured at one time. Many contractors pour the stem first.

I have no further criticisms to offer, as the report after Paragraph 71 meets with my approval. The portions however that relate to the practical outdoor work and in which the outdoor man will be most greatly interested are, to my mind, decidedly insufficient.

Mr. Thompson. MR. SANFORD E. THOMPSON (by letter).—The discussion which has been presented on the Report on Reinforced Concrete should be of valuable assistance to the present Committee, and the suggestions made should be carefully considered with a view to incorporating in the next report as many of them as it is deemed advisable.

Perhaps the most important questions are those referred to by each of the gentlemen taking part in the discussion, although they are considered from different points of view,—the quality and the working stress in steel for reinforced concrete. A limiting stress of 16,000 lbs. per sq. in. was decided upon as a value to adopt for the present. Special conditions and material of exceptional quality may sometimes warrant slightly higher values. The subject is one which deserves careful attention, and is being considered by the committees of several of our national associations.

A few comments may be added upon several of the paragraphs:

Paragraph 6. With reference to the effect of sea water, it may be said that in the opinion of the writer, it has not yet been proved that only cement high in lime is injured by sea water, although this is probably affected the most.

Paragraphs 16-21 recommend tests for sand. When, as shown in the Appendix, mortar made from the sand from one natural bank gives a tensile strength of 80 pounds at 7 days, while another gives a strength of 263 pounds at the same age,

both sands being clean and the only difference being in the size of the grains, it does not seem that too great stress can be placed upon the importance of proper selection and test. The writer has been called upon frequently during the last two or three years to investigate concrete which was defective because of poor sand. The strength of the mortar is of the first importance, while, if the sand is clean, the determination of the mechanical analysis will afford very exact indication of the relative value of different sands. Mr. Thompson.

The practice in proportioning is by no means uniform throughout the country, the units of measure varying from 3.3 to 4.25 cu. ft. The most important point is to have some unit which will be generally adopted, and 3.8 cu. ft. is given in Paragraph 31 as having been adopted in much of the largest engineering and contracting practice.

Paragraph 47. The word "structure" was intentional. It is possible in many classes of reinforced concrete, such as tanks, to pour the entire structure at one operation, and this plan should be followed when practicable; in building construction it is obviously not possible.

Paragraph 57. A lower bearing value is suggested for beams run into pockets in a wall, than in cases where the member is smaller than the base upon which it rests, because of the greater difficulty of properly placing the concrete.

Paragraph 102. The meaning intended is as stated, that the column rods should be straight so that they will set vertical and true.

REPORT OF COMMITTEE ON TESTING CEMENT AND CEMENT PRODUCTS.

By E. S. Larned,* Chairman.

In considering material for the annual report of this Committee, it was deemed an opportune time to invite some form of original research work, for which each member is specially equipped by reason of long experience and responsible connection with an established laboratory of recognized authority.

It was also expected that by individual effort and initiative, some variety of subjects could be taken up, each of which would prove of special interest and value to the Association, but this proved impracticable, and accordingly a definite program of tests was outlined and each member invited to carry same through for purposes of comparison, and to serve also as a check in drawing conclusions from the results obtained.

The influence of temperature upon the setting and hardening of cements has long been recognized as an important factor, and some tests have been made to determine this, results appearing in the more or less scattered and elusive cement literature, but it is believed that much information is yet to be gained from investigation along this line and it is to be regretted that the laboratory cannot more faithfully reproduce the conditions of every day field practice.

The test suggested for this report was to determine the influence of varying temperatures in the gaging water upon the setting properties and tensile strength of three kinds of commercial Portland cement, viz., quick setting (taking the initial set preferably under ten minutes), normal cement, and very slow setting cement. The pats for determination of set and the briquettes, as soon as made, were exposed in dry air at a temperature of about 110 degrees F. This exposure was intended to

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approximate some of the extreme conditions experienced in hot summer weather in practical operations.

Each night, during the full period of the test, the temperature was allowed to fall to that of the laboratory and was raised the following morning and maintained during the day at about 110 degrees F. After the early hardening of the briquettes, it was aimed to maintain the humidity of the air in the pans, containing the test specimens, between 60 and 80 degrees; this could not be regulated in the early stages under the conditions to be met.

The different samples of cement and the standard laboratory sand used, were allowed to gain and remain at the laboratory temperature prior to mixing, but the gaging water ranged in temperature from 40 degrees F. to boiling, at 10-degree intervals up to 120 degrees, then raised to 150 degrees, and then to boiling.

For purposes of comparison, the usual normal tests, in accordance with the standard specifications of the American Society for Testing Materials,* and a chemical analysis, were made of the same cements.

Under the conditions named for the special test, it will be observed at once that the temperature of the cement, sand, molds and laboratory would neutralize to a large extent the temperature of the gaging water above and below this normal average, the percentage of water used being relatively so small. It must also be noted that the influence of these unusual laboratory conditions upon the rate of set and tensile strength of small test specimens would be more intense than similar conditions upon large masses of cement, mortar or concrete. The test specimens were, however, not exposed to air currents, as would be the case in newly-laid and unprotected sidewalks, floors, and other forms of concrete construction having large superficial area compared to volume.

With the experience gained from these tests, the laboratories that did the work could probably repeat the series with more satisfactory results, and it has been suggested that it would be desirable to bring all the materials used to the same temperature as the mixing water and kept uniform during the process

*Standard No. 1, National Association of Cement Users.

of mixing; this would be even more apparent, were it possible to have the temperature, during exposure, conform and be maintained constant with the temperature of the materials as first combined.

Had all the laboratories represented in this Committee been able to undertake this investigation, it was not expected that the results would be uniform, for the reason that each member was to select his own sample of cement (of the three kinds named), and was further obliged to adapt the apparatus most convenient in hand, to secure the conditions of exposure stipulated. It was expected, however, that all results reported would lead to the same general conclusions, and this proved to be substantially correct in the two reports received, namely, from Mr. J. Y. Jewett and Mr. H. L. Sherman.

Owing to the multiplicity of figures in the tables only one full set will be given, and attention called to material differences, when any, in the form of foot-notes.

Quick setting cement gave the usual trouble in mixing and molding, making it difficult and practically impossible to secure uniform results in this operation.

The normal and slow setting cements were mixed and molded with a good degree of uniformity, and the variations in tensile strength are probably due largely to variations in the condition of exposure of the different briquettes, especially while setting and during the early period of hardening, which variations could not have readily been avoided without the expenditure of considerably more time, and the use of more elaborate equipment.

TABLES.

Cement.—Sample No. 1 was obtained from an eastern mill, especially for the purpose of these tests, and it was claimed that this sample had not been treated with calcium sulphate (the custom of the mill being to add the sulphate after grinding the cement).

Sample No. 2 is a western cement.

Sample No. 3 is a western cement, the manufacturers claiming that they do not use any calcium sulphate in their

product as, owing to the high percentage of iron which it contains, it is sufficiently slow setting without such admixture.

SUMMARY OF RESULTS.

Setting.—The use of mixing water of a high temperature makes a quick cement slower setting, even in dry air of 110 degrees F., while the slow setting cements become considerably quicker setting under this exposure, without regard to the variations in the mixing of water (see foot-note under sample No. 2).

Water.—The least amount of water required to produce "normal consistency" was uniformly found to be at the lowest temperature used, namely 40 degrees F., while the amount necessary gradually increased as the temperature was raised, the *apparent* difference reaching a maximum of over six per cent.; this difference, however, is accounted for in part by the increase in volume of the water as the temperature rises.

Tensile Strength.—Briquettes kept in the air at 110 degrees F. (and broken when at that temperature) show in general a marked decrease in strength as compared with the normal tests, and also show in general a lower rate of increase from the 1-day to the 7-day, and from the 7-day to the 28-day periods, this being in some cases a decrease rather than an increase.

Appearance of Pats and Briquettes.—It was expected that unfavorable indications, in the way of crazing, checking, warping or cracking, would follow exposure in dry air at 110 degrees F., but one report states that nothing of this nature was observed in any of the samples, while the other states that the slower setting cement was free from these indications, but the quick cement gave signs of cracking in the pats, although the same cement in the briquettes proved all right.

In order to study the influence of mixing water of varying temperature upon the tensile strength of briquettes kept 24 hours in moist closet and the remainder of the period in water at normal laboratory temperature, a special series was made and results will be found in Table IV.

The Chairman of this Committee desires to express his appreciation of the painstaking and generous coöperation, and of the courteous and helpful correspondence received from all members of the Committee throughout the year.

TABLE I. Sample No. 1. Quick Setting. (An Eastern Cement.)

The Influence of varying temperatures of the Gaging Waters upon the setting properties and tensile strength of neat Portland Cement.

FINENESS.	Residue on No. 100 sieve.....	1.0 per cent.
	No. 200 sieve.....	16.0 "
NORMAL TEST.	Temperature of Water.....	70° F.
	" " Room.....	68° F.
	" " Moist Closet.....	68° F.
	Initial set, immediate.	
	Final set, 4 hours, 15 min.	
	Constancy of volume, 28 days in air.....	O. K.
	Constancy of volume, 1 day in moist air, 27 days in water.....	O. K.
ACCELERATED TEST.	Constancy of volume, 1 day in moist air, 5 hrs. in steam.....	O. K.
ANALYSIS.	Silica (SiO_2).....	22.00 per cent.
	Alumina and Iron (Al_2O_3 and Fe_2O_3).....	8.58 "
	Iron (Fe_2O_3).....	2.03 "
	Lime (CaO).....	62.66 "
	Magnesia (MgO).....	3.53 "
	Anhydrous Sulphuric Acid (SO_3)	0.36 "
NORMAL TENSILE TESTS	(2 briquettes each period, normal water).....	21.9 "
	24 hours neat.....	Average 210
	7 days neat.....	" 620
	7 " sand (1-3).....	" 247
	28 " neat.....	" 695
	28 " sand (1-3).....	" 271
SPECIFIC GRAVITY		3.14

Pats and briquettes exposed in dry air, at temperature of about 110° F.

TABLE I (Continued).

Water.		Setting Time.		Tensile Tests.			
Temperature.	Per cent.	Initial.	Final.	24 hours.	7 days.	28 days.	
		H. M.	H. M.				
40° F.....	21.5		1 20	130	323	350	N
					152	259	S
50° F.....	21.5		1 20	164	291	393	N
					146	142	S
60° F.....	21.9	Immediate.	1 45	170	272	372	N
					160	165	S
75° F.....	22.0		2 00	171	236	232	N
					135	132	S
90° F.....	22.3		2 15	150	273	398	N
					139	149	S
100° F.....	22.3		2 40	130	277	315	N
					110	130	S
110° F.....	23.1	0 1	3 00	174	249	366	N
					154	125	S
120° F.....	23.1	0 2	3 00	148	275	339	N
					164	200	S
150° F.....	24.6	0 4	3 15	192	258	302	N
					155	170	S
Boiling.....	26.2	1 00	4 00	185	332	320	N
					145	132	S

NOTE.—N indicates neat briquettes.
S indicates mortar briquettes mixed 1 to 3.

TABLE II. Sample No. 2. Normal or medium as to setting time.
(A Western Cement.)

The influence of varying temperatures of the Gaging Water upon the setting properties and tensile strength of neat Portland Cement.

FINENESS. Residue on No. 100 sieve..... 5.0 per cent.
No. 200 sieve.....21.6 "

TABLE II (Continued).

NORMAL TEST.	Temperature of Water	70° F.
	" " Room	68° F.
	" " Moist Closet	68° F.
	Initial set, 4 hours, 15 min.	
	Final set, 8 hours, 15 min.	
	Constancy of volume, 28 days in air	O. K.
	Constancy of volume, 1 day in moist air, 27 days in water	O. K.
ACCELERATED TEST	Constancy of volume, 1 day in moist air, 5 hrs. in steam	O .K.
ANALYSIS.	Silica (SiO_2)	22.12 per cent.
	Alumina and Iron (Al_2O_3 and Fe_2O_3)	9.74 "
	Iron (Fe_2O_3)	2.18 "
	Lime (CaO)	62.28 "
	Magnesia (MgO)	.78 "
	Anhydrous Sulphuric Acid (SO_3)	1.60 "
NORMAL TENSILE TESTS.	(2 briquettes each period, normal water)	20.7 "

24 hours	neat	Average	350
7 days	neat	"	617
7 "	sand (1-3)	"	239
28 "	neat	"	664
28 "	sand (1-3)	"	362

SPECIFIC GRAVITY. 3.12

SET.

Water.		Initial Set.	Final Set.
Temperature.	Per cent.		
40° F.	22	12 min.	70 min.
50° F.	22	10 "	70 "
60° F.	22	10 "	70 "
75° F.	22	12 "	80 "
90° F.	22	13 "	90 "
100° F.	22	15 "	90 "
110° F.	22½	20 "	90 "
120° F.	23	20 "	90 "
150° F.	24	25 "	95 "
Boiling	25	28 "	100 "

TABLE III. Sample No. 3. Slow setting. (A Western Cement.)

The influence of varying temperatures of the Gaging Water upon the setting properties and tensile strength of neat Portland Cement.

FINENESS.	Residue on No. 100 sieve.....	3.6 per cent.
	No. 200 sieve.....	22.4 "
NORMAL TEST.	Temperature of Water.....	70° F.
	" " Room.....	68° F.
	" " Moist Closet.....	68° F.
	Initial set, 8 hours, 00 min.	
	Final set, 16 hours, 00 min.	
	Constancy of volume, 28 days in air.....	O. K.
	Constancy of volume, 1 day in moist air, 27 days in water.....	O. K.
ACCELERATED TEST.	Constancy of volume, 1 day in moist air, 5 hours in steam.....	O. K.
ANALYSIS.	Silica (SiO_2).....	18.96 per cent.
	Alumina and Iron (Al_2O_3 and Fe_2O_3).....	14.26 "
	Iron (Fe_2O_3).....	7.09 "
	Lime (CaO).....	63.08 "
	Magnesia (MgO).....	.82 "
	Anhydrous Sulphuric Acid (SO_3)	.83 "
NORMAL TENSILE TESTS.	(2 briquettes each period, normal water).....	20.5 "
	24 hours neat.....	Average 175
	7 days neat.....	" 494
	7 " sand (1-3).....	" 177
	28 " neat.....	" 723
	28 " sand (1-3).....	" 291
SPECIFIC GRAVITY.		3.22

TABLE III (Continued).

Pats and briquettes exposed in dry air, at temperature of about 110° F.

Water.		Setting Time.		Tensile Tests.			
Temperature.	Per cent.	Initial.	Final.	24 hours.	7 days.	28 days.	
40° F.....	20.2	All about 2 hrs. 15 min.	All about 4 hrs. 30 min.	367	280 140	428 180	N S
50° F.....	20.3			351	311 151	463 227	N S
60° F.....	20.3			400	307 193	357 200	N S
75° F.....	20.7			277	281 196	427 214	N S
90° F.....	20.8			306	315 138	387 221	N S
100° F.....	20.8			312	297 151	366 175	N S
110° F.....	21.2			306	322 179	366 206	N S
120° F.....	21.3			333	288 228	241 179	N S
150° F.....	22.0			302	295 217	170 237	N S
Boiling.....	22.1			229	295 181	323 145	N S

NOTE.—N indicates neat briquettes.
S indicates mortar briquettes mixed 1 to 3.

TABLE IV. Sample No. 4. Cement from the Lehigh Valley District.

Varying temperatures in mixing water. Briquettes kept in moist air closet 24 hours and remainder of time in water at normal laboratory temperatures.

FINENESS. Residue on No. 100 sieve..... 7.4 per cent.
No. 200 sieve.....23.4 "

SETTING. Normal test, initial 155 min.
Final, 345 min.

SOUNDNESS. Normal and Accelerated.....K. O.

Mixing Water.		Tensile Strength, lbs. per sq. inch.				
		Neat Cement.		Water Per cent.	1-3 Standard Sand.	
Temperature.	Per cent.	7 days.	28 days.		7 day.	28 day.
40° F.....	22	570	658	9	164	306
50° F.....	22	589	680	9	208	321
72° F.....	22	581	649	9	234	358
100° F.....	22	606	698	9	240	337
110° F.....	22	586	634	9	219	312
120° F.....	22	580	627	9	213	304
150° F.....	24	604	607	9¼	178	288
Boiling.....	25	467	598	10	149	267

ANALYSIS. Silica (SiO_2).....23.58 per cent.
Alumina and Iron (Al_2O_3 and Fe_2O_3)..... 8.20 "
Iron (Fe_2O_3)..... 2.53 "
Magnesia (MgO)..... 2.74 "
Anhydrous Sulphuric Acid (SO_3) 1.30 "

TABLE IV (Continued).

Pats and briquettes exposed in dry air, at temperature of about 110° F.

Water.		Setting Time.		Tensile Tests.			
Temperature.	Per cent.	Initial.	Final.	24 hours.	7 days.	28 days.	
40° F.....	20.3	All about 1 hr. 15 min.	All about 2 hrs. 30 min.	249	299	396	N
					192	179	S
50° F.....	20.3			247	236	331	N
					207	194	S
60° F.....	20.7			311	331	379	N
					200	217	S
75° F.....	21.0			281	241	223	N
					238	273	S
90° F.....	21.4			249	234	359	N
					230	208	S
100° F.....	21.4			281	265	356	N
					234	294	S
110° F.....	21.5			309	338	341	N
					153	242	S
120° F.....	21.5			317	306	347	N
					236	292	S
150° F.....	24.5			319	261	228	N
					164	175	S
Boiling.....	26.7			281	224	266	N
					158	127	S

NOTE.—N indicates neat briquettes.
S indicates mortar briquettes mixed 1 to 3.

While the rate of set in dry air at 110° F., in the above table, appears much accelerated over the normal, it is not so marked as in the case of another test reported under the same conditions, in which the retarding influence of the higher temperatures of mixing water also appears, results of which follow:

SAMPLE.	From Lehigh District.	
NORMAL SET.	Initial 90 min., Final 380 min.	
FINENESS.	Residue on No. 100 sieve..... 7.4	per cent.
	No. 200 sieve.....23.4	"
SOUNDNESS.	Normal and Accelerated.....O. K.	

Pats exposed in dry air at 110° F.

STANDARD No. 3.

NATIONAL ASSOCIATION OF CEMENT USERS.

PHILADELPHIA, PA.

STANDARD SPECIFICATIONS FOR CEMENT HOLLOW BUILDING BLOCKS

ADOPTED JANUARY, 1908.
REVISED JANUARY, 1909.

REGULATIONS GOVERNING USE AND MANUFACTURE.

Hollow cement blocks made in accordance with the following specifications, and meeting the requirements thereof, may be used in building construction, subject to the usual form of approval, required of other materials of construction, by the bureau of building inspection.

1. **Cement.** The cement used in making blocks shall be Portland cement, capable of passing the requirements as set forth in the "Standard Specifications for Cement," of the American Society for Testing Materials, and adopted by this Association (Standard No. 1) January, 1906.

2. **Sand.** The sand used shall be suitable siliceous material, passing the one-fourth inch mesh sieve, clean, gritty and free from impurities.

3. **Stone Aggregate** This material shall be clean broken stone, free from dust, or clean screened gravel passing the three-quarter (¾) inch, and refused by the one-quarter (¼) inch mesh sieve.

4. **Unit of Measurement.** The barrel of Portland cement shall weigh 380 pounds net, either in barrels or sub-divisions thereof, made up of cloth or paper bags, and a cubic foot of cement shall be called not to exceed 100 pounds or the equivalent of 3.8 cubic feet per barrel. Cement shall be gauged or measured either in the original package as received from the manufacturer, or may be weighed and

so proportioned; but under no circumstances shall it be measured loose in bulk.

5. Proportions. For exposed exterior or bearing walls.

(a) Hollow cement blocks, machine made, using semi-wet concrete or mortar, shall contain one (1) part cement, not to exceed three (3) parts sand, and not to exceed four (4) parts stone of the character and size before stipulated. When the stone shall be omitted the proportions of sand shall not be increased, unless it can be demonstrated that the percentage of voids and tests of absorption and strength allow in each case of greater proportions with equally good results.

(b) When said blocks are made of slush concrete, in individual molds and allowed to harden undisturbed in same before removal, the proportions may be one (1) part cement to not exceed three (3) parts sand and five (5) parts stone, but in this case also, if the stone be omitted the proportion of sand shall not be increased.

6. Mixing. Thorough and vigorous mixing is of the utmost importance.

(a) Hand mixing. The cement and sand in correct proportions shall first be perfectly mixed dry, the water shall then be added carefully and slowly in proper proportions and thoroughly worked into and throughout the resultant mortar; the moistened gravel or broken stone shall then be added, either by spreading the same uniformly over the mortar, or spreading the mortar uniformly over the stones, and then the whole mass shall be vigorously mixed together until the coarse aggregate is thoroughly incorporated with and distributed throughout the mortar.

(*b*) Machine mixing. Preference shall be given to machine mixers of suitable design and adapted to the particular work required of them; the sand and cement, or sand and cement and moistened stone shall, however, be first thoroughly mixed before the addition of water, and then continued until the water is uniformly distributed or incorporated with the mortar or concrete; *provided,* however, that when making slush or wet concrete (such as will quake or flow) this procedure may be varied with the consent of the bureau of building inspection, architect or engineer in charge.

7. **Molding.** Due care shall be used to secure density and uniformity in the blocks by tamping or other suitable means of compression. Tamped blocks shall not be finished by simply striking off with a straight edge, but, after striking off, the top surfaces shall be trowelled or otherwise finished to secure density and a sharp and true arris.

8. **Curing.** Every precaution shall be taken to prevent the drying out of the blocks during their initial set and first hardening. A sufficiency of water shall first be used in the mixing to perfect the crystallization of the cement, and, after molding, the blocks shall be carefully protected from wind-currents, sunlight, dry heat or freezing for at least five (5) days, during which time additional moisture shall be supplied by approved methods, and occasionally thereafter until ready for use.

9. **Ageing.** Hollow cement blocks in which the ratio of cement to sand be one-third (⅓) (one part cement to three parts sand) shall not be used in the construction of any building until they have attained the age of not less than three (3) weeks.

Hollow cement blocks in which the ratio of cement to sand be one-half (½) (one part cement to two parts sand) may be used in construction at the age of two (2) weeks, with the special consent of the bureau of building inspection and the architect or engineer in charge.

Special blocks of rich composition, required for closures, may be used at the age of seven (7) days with the special consent of the same authorities.

The time herein named is conditional, however, upon maintaining proper conditions of exposure during the curing period.

10. **Marking.** All cement blocks shall be marked, for purposes of identification, showing name of manufacturer or brand, date (day, month and year) made, and composition or proportions used, as, for example, 1-3-5, meaning one cement, three sand and five stone.

11. **Thickness of Walls.** The thickness of bearing walls for any building where hollow cement blocks are used may be ten (10) per cent. less than is required by law for brick walls. For curtain walls or partition walls, the requirements shall be the same as in the use of hollow tile, terra cotta or plaster blocks.

12. **Party Walls.** Hollow cement blocks shall not be permitted in the construction of party walls, except when filled solid.

13. **Walls—Laying off.** Where the face only is of hollow cement block, and the backing is of brick, the facing of hollow block must be strongly bonded to the brick, either with headers projecting four (4) inches into the brick work, every fourth course being a header course, or with approved ties, no brick backing to be less than eight (8) inches. Where the walls are made entirely of concrete blocks, but where said blocks have not the same width as the wall, every fifth course shall extend through the wall, forming a secure bond, when not otherwise sufficiently bonded. All walls, where blocks are used, shall be laid up with Portland cement mortar.

14. **Girders or Joists.** Wherever girders or joists rest upon walls so that there is a concentrated load on the block of over two (2) tons, the blocks supporting the girder or joists must be made solid for at least eight (8) inches from the inside face. Where such concentrated load shall exceed five (5) tons, the blocks for at least three courses below, and for a distance extending at least eighteen (18) inches each side of said girder, shall be made solid for at least eight (8) inches from the inside face. Wherever walls are decreased in thickness, the top course of the thicker wall shall afford a full solid bearing for the webs or walls of the course of blocks above.

15. **Limit of Loading.** No wall, nor any part thereof, composed of hollow cement blocks, shall be loaded to an excess of eight (8) tons per superficial foot of the area of such blocks, including the weight of the wall, and no blocks shall be used in bearing walls that have an average crushing at less than 1,000 pounds per square inch of area at the age of twenty-eight (28) days; no deduction to be made in figuring the area for the hollow spaces.

16. **Sills and Lintels.** Concrete sills and lintels shall be reinforced by iron or steel rods in a manner satisfactory to the bureau of building inspection and the architect or engineer in charge, and any lintels spanning over 4 feet 6 inches shall rest on block solid for at least 8 inches from the face next the opening and for at least three courses below the bottom of the lintel.

17. **Hollow Space.** The hollow space in building blocks used in bearing walls

shall not exceed the percentage given in the following table for different height walls, except where blocks containing a greater percentage shall be proven by actual test to meet all the test requirements herein specified to the satisfaction of the bureau of building inspection, and in no case shall the walls or webs of the block be less in thickness than one-fourth their height. The figures given in the table represent the percentage of such hollow space for different height walls:

Stories	1st	2d	3d	4th	5th	6th
1 and 2	33	33				
3 and 4	25	33	33	33		
5 and 6	20	25	25	33	33	33

18. **Application for Use.** Before any such material be used in buildings, an application for its use and for a test of the same must be filed with the bureau of building inspection. In the absence of such a bureau, the application shall be filed with the chief of any department having such matters in charge. A description of the material and a brief outline of its manufacture and proportions used must be embodied in the application. The name of the firm or corporation and the responsible officers thereof, shall also be given, and changes in same thereafter promptly reported.

19. **Preliminary Test.** No hollow cement blocks shall be used in the construction of any building unless the maker of said blocks has submitted his product to the full tests required herein, and placed on file with the bureau of building inspection, or other duly authorized official, a certificate, from a reliable testing laboratory, showing that representative samples have been tested and successfully passed all the requirements hereof, and giving in detail the results of the tests made.

No cement blocks shall be used in the construction of any building until they have been inspected and approved, or, if required, until representative samples be tested and found satisfactory. The results of all tests made, whether satisfactory or not, shall be placed on file in the bureau of building inspection. These records shall be open to inspection upon application, but need not necessarily be published.

20. Additional Tests. The manufacturer and user of such hollow cement blocks, or either of them, shall, at any and all times, have made such tests of the cements used in making such blocks, or such further tests of the completed blocks, or of each of these, at their own expense and under the supervision of the bureau of building inspection, as the chief of said bureau shall require.

In case the result of tests made under this condition should show that the standard of these regulations is not maintained, the certificate of approval issued to the manufacturer of said blocks will at once be suspended or revoked.

21. Certificate of Approval. Following the application called for in clause No. 18 and upon the satisfactory conclusion of the tests called for, a certificate of approval shall be issued to the maker of the blocks by the bureau of building inspection. This certificate of approval will not remain in force for more than four months, unless there be filed with the bureau of building inspection, at least once every four months following, a certificate from some reliable physical testing laboratory showing that the average of at least three (3) specimens tested for compression and at least three (3) specimens tested for transverse strength comply with the requirements herein set forth, the said samples to be selected by a building inspector or by the laboratory from blocks actually going into construction work.

22. Test Requirements. Hollow cement blocks must be subjected to the following tests: Transverse, compression and absorption, and may be subjected to the freezing and fire tests, but the expense of conducting the freezing and fire tests will not be imposed upon the manufacturer of said blocks.

The test samples must represent the ordinary commercial product, of the regular size and shape used in construction. The samples may be tested as soon as desired by the applicant, but in no case later than sixty days after manufacture.

Transverse Test. The modulus of rupture for concrete blocks at twenty-eight days must average 150, and must not fall below 100 in any case.

Compression Test. The ultimate compressive strength at twenty-eight days must average one thousand (1,000) pounds per square inch, and must not fall below 700 in any case.

Absorption Test. The percentage of absorption (being the weight of water absorbed divided by the weight of the dry sample) must not average higher than 15 per cent., and must not exceed 22 per cent. in any case.

23. **Condemned Block.** Any and all blocks, samples of which, on being tested under the direction of the bureau of building inspection, fail to stand at twenty-eight (28) days the tests required by this regulation, shall be marked "condemned" by the manufacturer or user and shall be destroyed.

24. **Cement Brick.** Cement brick may be used as a substitute for clay brick. They shall be made of one part cement to not exceeding four parts clean sharp sand, or one part cement to not exceeding three parts clean sharp sand and three parts broken stone or gravel passing the ½-inch and refused by the ¼-inch mesh sieve. In all other respects, cement brick must conform to the requirements of the foregoing specifications.

STANDARD METHOD OF TESTING.

25. **Method of Testing.** 1. All tests required for approval shall be made in some laboratory of recognized standing, under the supervision of the engineer of the bureau of building inspection or the architect or engineer in charge, or all of these. The manufacturer may be present or represented during said tests, if he so desires. Approval tests are made at the expense of the applicant.

2. For the purposes of the tests, at least twelve (12) samples or test pieces must be provided. Such samples must represent the ordinary commercial product and may be selected from stock by the bureau of building inspection, or in the absence of such a bureau, by the architect or engineer in charge.

In cases where the material is made and used in special shapes or forms, too large for testing in the ordinary machines, smaller sized specimens shall be used as may be directed.

3. In addition to the tests required for approval, the weight per cubic foot of the material must also be obtained and recorded.

4. Tests shall be made in series of at least three (3), except that in the fire tests a series of two (four samples) are sufficient.

Transverse tests shall be made on full-sized samples. Half

samples may be used for the crushing, freezing and fire tests. The remaining samples are kept in reserve, in case duplicate or confirmatory tests be required. All samples must be marked for identification and comparison.

5. The transverse test shall be made as follows: The samples shall be placed flatwise on two rounded knife edge bearings set parallel 7 inches apart. A load is then applied on top, midway between the supports, and transmitted through a similar rounded knife edge, until the sample is ruptured. The modulus of rupture shall then be determined by multiplying the total breaking load in pounds by 3 l (three times the distance between supports in inches) and then dividing the result thus obtained by twice the product of the width in inches by the square of the depth in inches. $R = \frac{3\,wl}{2\,bd^2}$ No allowance should be made in figuring the modulus of rupture for the hollow spaces.

6. The compression test shall be made as follows: Samples must be cut from blocks, so as to contain a full web section. The sample must be carefully measured, then bedded flatwise in plaster of Paris, to secure a uniform bearing in the testing machine, and crushed. The total breaking load is then divided by the area in compression in square inches, no deduction to be made for hollow spaces; the area will be considered as the product of the width by the length.

7. The absorption test shall be made as follows: The sample is first thoroughly dried to a constant weight, at not to exceed 212° F. The weight must be carefully recorded. It is then placed in a pan or tray of water, face downward, immersing it to a depth of not less than 2 inches. It is again carefully weighed at the following periods: Thirty minutes, four hours, and forty-eight hours, respectively, from the time of immersion, being replaced in the water in each case as soon as the weight is taken. Its comprehensive strength, while still wet, is then determined at the end of the forty-eight hours period, in the manner specified in Section 6.

8. The freezing test shall be made as follows: The sample is immersed, as described in Section 7, for at least four hours, and then weighed. It is then placed in a freezing mixture or a refrigerator, or otherwise subjected to a temperature of less

than 15° F. for at least twelve hours. It is then removed and placed in water, where it must remain for at least one hour, the temperature of which is at least 150° F. This operation is repeated ten (10) times, after which the sample is again weighed while still wet from the last thawing. Its crushing strength should then be determined, as called for in Section 6.

9. The fire test is made as follows: Two samples are placed in a cold furnace in which the temperature is gradually raised to 1700° F. The test piece must be subjected to this temperature for at least thirty minutes. One of the samples is then plunged in cold water (about 50° to 60° F.) and the results noted. The second sample is permitted to cool gradually in air, and the result noted.

10. The following requirements must be met to secure an acceptance of the materials: The modulus of rupture for concrete blocks at twenty-eight days must average 150, and must not fall below 100 in any case. The ultimate compressive strength at twenty-eight days must average 1,000 pounds per square inch, and must not fall below 700 in any case. The percentage of absorption (being the weight of water absorbed divided by the weight of the dry sample) must not average higher than 15 per cent., and must not exceed 22 per cent. in any case. The reduction of compressive strength must not be more than $33^1/_3$ per cent., except that when the lower figure is still above 1,000 pounds per square inch, the loss in strength may be neglected. The freezing and thawing process must not cause a loss in weight greater than 10 per cent., nor a loss in strength of more than $33^1/_3$ per cent., except that when the lower figure is still above 1,000 pounds per square inch, the loss in strength may be neglected. The fire test must not cause the material to disintegrate.

TOPICAL DISCUSSION ON CONCRETE BLOCKS.

On Fire-Resistive Properties.

Mr. Gill. Mr. J. Robert Gill.—At the last Convention Mr. Humphrey described the government tests on the fire-resistive properties of concrete blocks. I would like to ask if there has been any progress in that work during the past year.

Mr. Humphrey. President Richard L. Humphrey.—The investigations as to the fire-resistive properties of cement blocks have been continued. Last year we tested some thirty panels, a large proportion of which were of blocks. Many webs of the blocks failed, and this year we have reinforced the webs. Owing to the dismantling of the old plant by reason of changes, the tests on these blocks will not be made until later in the year.

In addition to panel tests we are now beginning at Pittsburg a series of experiments on the rates of heat conductivity of concrete and mortars. The test specimens are panels of various mixtures. Electric couples are imbedded at different distances from the surface and heat is applied. The amount of heat is registered at certain intervals by the electric couples or thermometers with the idea of determining the proper amount of insulation or the necessary thickness of concrete to protect a concrete wall from a fire of a certain intensity and duration.

These fire tests are being made on relatively small specimens, with the object of studying the relative rates of the heat conductivity of the various building materials which are really the basis of all fire investigations. The others are perhaps more spectacular, but this study is the real basic principle of the fire-resistive properties of various building materials. After these tests are completed the facts established will be applied to larger structures, that is, structures that are actually comparable with existing buildings, for the purpose of studying just how these theories are borne out in the actual structure.

The trouble with the cement block as with the clay tile lies in the lack of strength in the web to withstand the unequal rates

Mr. Humphrey.

of expansion of the face and back, produced by high temperatures. A material that is a comparatively good non-conductor of heat, when subject to a very intense heat on one face, will expand unequally, one face expanding more than the other. By reason of the fact that the material is a poor conductor it will expand one face more rapidly than the heat can be conducted through to the other side and unequal expansion results. The expansion will cause a cracking of the webs unless there is sufficient strength in them to overcome it. Now if the web of a cement block is very thin and is made as many blocks are, of a very dry and very lean mortar or concrete, the strength is insufficient to resist the expansion and of course a crack occurs right across the web and that face may drop off. By increasing the thickness of the web and also by increasing the thickness of the walls of the block, you are providing a means of resisting this expansion. To secure a proper block, therefore, it is necessary to make it so strong that the web has sufficient strength to resist the expansion. One reason why we tried the experiment of putting reinforcement in the web was for the purpose of strengthening the web to resist such action. Cement mortar or concrete is deficient in tension and under such conditions the block is subject to tensile stresses.

In every case where we have tested blocks they have been allowed to cure at least sixty days, and some of them were considerably older. In some of the tests we are now making, the blocks have been cured six months, for the purpose of determining whether a block that has dried out and is no longer green offers more resistance to fire than a green one. There is no doubt that a block that is quite green offers less resistance to fire than an old and thoroughly dried one for the reason that the moisture which is in the green block is volatilized by the heat, causing a sweating and disintegration of the block. Of course as a rule fires do not strike reinforced concrete blocks until they are at least six months or more old, but there are cases where there may have been a fire immediately after or during construction; but as a rule it is several years before a fire occurs. The older a block, the more advantageous it is for it, as far as its fire-resistive qualities are concerned.

Mr. Genther. MR. WILLIAM J. GENTHER.—I would like to ask whether a block with a reinforced web would fracture or have a crack?

Mr. Humphrey. PRESIDENT HUMPHREY.—I think it is quite probable that it would crack; but as long as the block is held together I do not know whether it would be a detriment. Of course, it is undesirable to have any fracture at all, but the crack would only be a thin hair crack.

I believe we are making a much better average cement block to-day than we were three or four years ago. At the same time, there is an immense number of poor blocks being made which have a detrimental effect on the industry, in that the man who makes a good block is at a decided disadvantage, because he must overcome the prejudice that has been caused by these bad blocks.

Mr. Chandler. MR. DANA G. CHANDLER.—I have been told that concrete blocks made of blue stone would not stand a fire, but a bank building made of such blocks successfully passed through a severe fire. Due to a lack of water they were not sprinkled while hot.

These blocks I refer to are faced with a 1-1½ mixture and 1-4 on the back. I would ask if you think the water would have any material effect on them. You can judge something about the heat, as the windows burned right out, frame and all.

Mr. Humphrey. PRESIDENT HUMPHREY.—The effect of water on a hot concrete building depends on a great many conditions. For instance, in the panel tests referred to, the panel was rolled right out of the furnace at a temperature of practically 1,700 degrees, and almost instantly quenched with cold water. In fact it was counterweighed so that it moved out in a fraction of a minute, and immediately a stream of water struck the heated surface. You can readily understand that when a white hot surface is suddenly quenched with water there results a contraction of this greatly expanded surface and it must necessarily do some damage, either by cracking or in the case of a weak block the surface begins to slough off. Blocks of 1-8 dry mixture do not show up very well; the disintegration is quite great. Blocks that are richer have the surface practically undamaged by this treatment. Now in a very hot fire the firemen cannot get as near as was the case in these panel tests, because the heat will prevent it,—so the

water will not come in direct contact; and besides if you produce a steaming effect on the water, as is often the case, it will help the cement to recrystallize, and you may restore the hardness of the surface if too much water has not been driven off. In other words the block that has been subjected to intense heat and the surface has been damaged by driving off the water necessary in the hardening of the cement, if subjected to moist atmosphere will absorb a certain amount of moisture and will again become hard. Of course there are cases where the fire is so hot and prolonged as to destroy the coherence of the concrete and the water stream will wash into pieces. In the case of natural building stone, the surface when similarly treated spalls off, especially in highly crystalline stone of the character of granite. **Mr. Humphrey.**

MR. GENTHER.—A party tested two cement bricks by putting them both in a forge and heating them until they were practically red. One was dropped in a tub of water and the other was allowed to cool naturally. The brick dropped in the tub of water shrank one inch in width but not at all in length. The other brick was practically intact and you could not tell it had been in the fire. I think the mixture was about 1-4. **Mr. Genther.**

PRESIDENT HUMPHREY.—All these phenomena are largely matters of expansion; it stands to reason that the smaller the piece subjected to the action of the fire, the less will be the effect of the expansion. For instance, a brick wall has a series of joints which are more or less compressible. The effect of heat is to expand it, but the joint takes up the compression, so that the destructive effect of the expansion is not so evident as in a much larger mass where there are fewer joints. So that is one reason, perhaps, why an ordinary brick wall will show up to so great advantage in a fire. Of course, the bricks themselves are clearly of a fire-resisting character since they are burned at a high temperature. The story is practically the same for the cement brick as in the ordinary clay brick. Of course, the condition where you take a very small brick or block of cement mortar or concrete and put it into a furnace and surround it on all sides with heat, there is no way of conducting off the heat, as you have the very worst condition possible, and a condition you will not get in ordinary conflagrations. In such cases it is **Mr. Humphrey.**

Mr. Humphrey. generally one face of the material that is subjected to the fire, and you have a mass back of it to conduct away the heat, and that very conduction of heat prevents the destruction of the exposed face.

ON QUALITY.

Mr. Perrot. MR. EMILE G. PERROT.—The question of concrete blocks is one that has occupied the attention of our firm for several years, and in the East we cannot get a satisfactory concrete block, from the simple fact that there is nobody who knows how to make them. We attempted to erect two buildings of concrete blocks, and I would not go through that experience again for what little I can get out of it. In one building a block maker said that the block would stand any test. It was a hydraulic pressed block. His process seemed to be excellent, so much so that we gave him the contract to construct the building of concrete blocks, with the understanding that the blocks must meet the requirements of the city of Philadelphia, which is a very fair test. In fact, it is almost the same as Standard No. 3 of this Association. The manager of the plant said that he could easily meet these requirements, but the question of ignorance entered into the making of the blocks to such an extent that the requirements were not met. He was going to make blocks of 1-2-4 concrete, which ordinarily would give a 2,000 pound compression test at 28 days. His 1-2-4 mixture was simply this: 1 cement, 2 sand and 4 grit or crushed stone; so that it made a 1-6 mortar mixture and no concrete at all. As a consequence the blocks failed and we had to leave the block proposition and build the walls of brick. This was the end of the block proposition in Philadelphia as far as our firm was concerned. We are now waiting for an active man who knows his business to turn up in Philadelphia and we will construct buildings on the lines suggested, if we can get blocks that will stand the test, and there is no reason why they should not do it.

Mr. Smith. MR. J. AUGUSTINE SMITH.—The greatest difficulty we find in the advancement of the use of concrete blocks has been the making of good blocks. I have had talks with architects and

they have no objections whatever to good concrete blocks but will not use the blocks being made in their locality. We have frequently gone to block manufacturers and told them the result of our experience. We instruct them how to make good blocks and they frequently claim to be making the finest kind of blocks and exhibit them. Well, it is enough to say that I would not use them, and yet they think they are making good blocks. Why? Because they do not apply themselves to their business and learn how; because they do not come to conventions where they may learn. If they do come they frequently do not attend the sessions where papers are read which will give them the knowledge necessary to improve the character of their product because they are too penurious to become members of this Association. **Mr. Smith.**

Concrete blocks will be used, and are used, when they are well made. An architect is quite willing and glad to use them if he can get them properly cured, blocks that will fulfill what he requires in the construction of his building. It is, therefore, imperative that the concrete block manufacturer be impressed with the fact that unless he turns out good work he cannot succeed in selling his product. It may be used in the shabby, ill-gotten looking buildings that are so frequently seen and which so seriously reflect upon the business of concrete block manufacturers, but there is a distinct movement, and a distinct development in this business that carries with it a good deal of consolation to the man who is honestly trying to up-lift and up-build, and we see this in the fine buildings that are now being constructed everywhere. It is the work of the manufacturer of machinery to up-lift the business by sending out literature, by sending out helpful hints to the manufacturer of blocks telling him what he should do and insist, if necessary, that this shall be done. It is better to refuse a sale than to sell machinery to a man who will make poor blocks, and I believe that unless this conclusion is concurred in by all machinery manufacturers, the business will not develop as fast as it should.

MR. W. F. WISELOGEL.—One of the troubles with the blocks is that they are made too cheap. The material is too lean in the first place, and then the blocks are rushed out as fast as possible, put into the building the next day and the money received for **Mr. Wiselogel.**

Mr. Wiselogel. them. I know of several instances where the blocks were put into the buildings very nicely and looked all right. In about thirty days cracks appeared, caused possibly by a little pebble being in the mortar. The mortar was not strong enough to resist that cracking, and of course the block is condemned. I believe that the block business should be handled just as carefully as reinforced concrete and sidewalks.

Foundation bricks are almost eliminated in our section of the country and concrete is used to the top of the ground and two or three courses of concrete blocks. Everyone recognizes that blocks are good, but a man will ask as to what is the matter with his foundation when there is a crack clear through three rows of blocks. Generally the concrete was too fresh and there was no strength to it. The strength only comes as it grows old and crystallizes. We are in too big a hurry, that is our trouble. We try to have our blocks 60 days old and six months if possible.

ON LINTELS.

Mr. Chandler. MR. DANA G. CHANDLER.—I have had some trouble with the cracking of reinforced lintels over doors. This was not caused by settling because the crack was the same width the whole distance up and in the outside face of the wall.

Mr. Wyatt. MR. FREDERICK E. WYATT.—I have made a number of lintels but have had no trouble. Sometimes in making concrete we are afraid and make it a little too rich, and the richer the mortar the more liable it is to crack. I have had trouble in that way but never with a mixture of 1-2-4 or 1-2-8. I built two or three barns with lintels 10 ft. long, and only 8 ins. high. They were well reinforced and carried a story and a half above. I have had no failures at all. The more cement we have in concrete, above a certain proportion, the more trouble we are liable to have with cracks.

Mr. Chandler. MR. CHANDLER.—The mixture was 1-3. The lintels are 8 ins. high and 4 ins. thick, backed up with a wooden lintel on account of the casing. Another lintel is 8 ins. square, reinforced in each corner with a half-inch rod, and a facing of 1½-1 and the backing is of 1-4 or 5 mixture. I cannot understand why the lintel should break in the center and not pull away at the end.

MR. WM. GENTHER.—I am building a concrete house and have many lintels. I make the mixture 1-1½, put them in place after three days and have no cracking. The lintels are properly reinforced however. **Mr. Genther.**

MR. CHANDLER.—The lintels are of a consistency so that we can trowel the face and make a nice smooth surface. They were fairly wet; not as wet as a sidewalk should be. **Mr. Chandler.**

The lintels over the doors being short were reinforced with ⅜ in. rods; one in the bottom, one in the center and one in the top. In the large lintel I used ½ in. rods at the bottom and two ⅜ in. above with hooks on each end of the rods.

MR. GENTHER.—Does the wood block lie on the wooden lintel used back of the basing? If there is any pressure from above there may be a thrust which tends to push the stone out so that it would not be cracked on the rear. There may be a fracture there but it is only open in the front, the heft being on the outer edge as the wood will shrink. I use lintels, both on the front and back, of the same size, 4 ins., 2 or 4 ins. in a 10 in. wall. **Mr. Genther.**

MR. S. F. BOYER.—I have made quite a number of lintels about 8 ft. long, reinforced with smooth galvanized wire. I had some trouble with them as they broke off entirely and since have been reinforcing with scrap iron from a washer factory, and I have had no trouble whatever. **Mr. Boyer.**

ON CURING.

MR. FREDERICK E. WYATT.—One of my problems at the present time is the economical handling of blocks. I haul them on trucks to the curing shed and unload them while green. After curing they are put on trucks again and taken to the storage yard. I intend to install a different system by which the blocks are put on the car and remain in the curing shed two or three days and are then hauled to the storage yard. I think the less a block is handled, especially while green, the better it is for the block and the more economical. A car will carry 8 or 10 blocks and for three or four machines which means about 150 cars, costing from $12 to $15 a car. I believe, however, that it is the proper **Mr. Wyatt.**

Mr. Wyatt. way to handle blocks, and am informed that the cars can be placed under a hood and the steam turned on. Thus the blocks are dried in much less time than by natural drying and in 24 hours the cars can be run out on the other end into the storage yard. It appears to me as a very simple matter and an economical way of handling the blocks.

Mr. Wiselogel. MR. W. F. WISELOGEL.—In regard to making blocks fast, I was asked to look at a new make of block machine, last summer, and everything was ready, just as handy as could be, and they made 21 blocks in 15 minutes. The sweat was rolling off the fellows in good shape. Now the manufacturer guaranteed this machine to make 21 blocks in 15 minutes; and it was true that they did this, but it was only 15 minutes that they worked. This is the way the claims of 600 or 700 blocks a day originate. I have not been able to make that many.

In the matter of curing, we installed a kiln. The blocks are placed upon a truck and run into the kiln, which uses a spray of exhaust steam. The result is a better cured and more beautiful block in a remarkably short time. By the old method if you were not careful a piece of the block is knocked off, or through some mishap it cracks and that crack never heals. The blocks are run in the kiln on the car, out to the transfer and placed in the storage yard. I believe it is the coming way to cure blocks as it makes them beautiful and you surely get the money out of them quicker. I believe the blocks should be put into the kiln and heated by steam, but to my mind the temperature should not be more than 80 to 100 degrees Fahrenheit.

Mr. Wyatt. MR. WYATT.—I am putting up a curing shed about 50 by 100 ft., adjacent to our mixing and manufacturing plant. There will be three lines of cars running into it by means of transfer tracks just the other side of the partition wall. Doors shutting off the curing shed will be provided, as the temperature there, about 75 degrees F., will be injurious to the mixing plant and too warm for the men. Our scheme is to run the cars on a transfer track and have the curing hoods on either side at the other end of the building. The cars will then stand six or seven hours before they get into the curing shed, four or six trucks will be placed in a steam heated section, after having been there over night they

will be ready to go to the storage yard, making room for the next lot. In that way we can probably run our temperature up to 75 or 80 degrees, using fine sprays which are of the Stearns type and give a vapor just like smoke for a radius of 30 ft. The sprayers are placed in the center of a pile of blocks about 30 ft. in diameter and keep them very moist in the curing room so as not to dry out. Mr. Wyatt.

MR. DANA G. CHANDLER.—I am installing a steam curing plant and would like to learn whether or not I should leave an air space under the doors at the end of the kilns. Some people claim there should be a circulation of air to help condense the steam, others claim the steam should condense naturally. Again, where should the pipe be placed to properly distribute the steam in the kilns? Mr. Chandler.

MR. E. S. HANSON.—A few weeks ago I visited a plant which began operations with the steam pipe coming in at the top of the kiln. After running this way for a short time, they went to the expense of changing the pipes to the floor, with a view of obtaining better diffusion of the steam. There are some very successful plants which have their pipes coming in near the roof, and the owners believe it is just as satisfactory. It does not seem to me advisable to have very much open space under the doors. Mr. Hanson.

MR. A. T. BRADLEY.—The great trouble seems to be, when the steam comes in at the bottom, that many of the lower blocks are liable to cure faster than the others, provided they are tiered; and the great thing is to regulate the steam and the moisture so it will be as even as possible. Mr. Bradley.

MR. F. A. FEATHERSTONE.—In the curing of cement blocks I find one of the great troubles has been the overheating of the blocks before they are sufficiently saturated with moisture. The ordinary cement block is made quite dry, with less moisture than is necessary for good concrete. The steam kiln is generally a very hot room, the temperature ranging from 120 degrees up to somewhere near the boiling point. All the water in the steam condenses on the ground, the walls, the tracks or the cars, and therefore, the air being dry, the effect on the blocks is to dry them out rather than to saturate them. My experience has been that Mr. Featherstone.

Mr. Featherstone. it is necessary to make blocks as wet as possible in the first place, and it is a very good plan, in case they are quite dry, to sprinkle them when they come in the curing room. The blocks should not go into the room immediately when hot water is used, it is not good practice, because the blocks are too warm to cause the steam to condense sufficiently. When the steam is discharged near the blocks themselves, it strikes the blocks first and condenses there. Otherwise it will condense on the walls, cars and on the tracks, doing the blocks very little good. It is good practice to thoroughly wet dry blocks, to discharge the steam as near the tracks as possible and to have the pipes go through the walls so as to keep them hot and prevent condensation on them. The trucks should be kept quite hot and the temperature in the curing room should be quite low at first, as the new blocks go in. As there is a considerable mass of the blocks or bricks, they will remain cold long enough to prevent the steam condensing on the trucks.

We have been following the above points on tubular pieces that we have used in forms for cement construction. We have not had much experience with cement blocks, but with thinner bricks we find that it is very necessary to have the steam condense directly on the bricks. We find very much better effects both in the speed of curing and in the quality of the brick. The great trouble with cement blocks is that they are liable to dry out during the first hour in the steam kiln more than they should.

In the matter of the time necessary to properly cure blocks I find that anywhere from 24 to 48 hours gives a very satisfactory effect when the concrete is not too dry in the first place. If the mixture is very dry it is difficult to get a perfect cure. A very wet mixture, however, thoroughly mixed and put into the kiln as stated, is very often cured in 24 hours. Blocks started in the morning can be taken out the next morning, but they should be kept in a moist atmosphere for a few days. In the case of pieces used for concrete forms, or concrete lumber, as it is called, thin pieces from 1 to 2 ins. thick, we find that in 36 hours we get a 7-day test and in about 5 days, keeping them in a moist atmosphere 5 or 6 hours, we get a 28-day test. Cement blocks cured from 36 to 48 hours will give the same result.

Mr. Featherstone.

It is not necessary to have the steam under pressure. It is really not steam curing but a hot water or moist air cure. No steam, as a rule, comes in contact with the blocks at all, but it is hot water vapor that condenses upon the surface. Therefore, it is a gradual sprinkling with very hot water, which is better than a high pressure steam cure, as it causes no chemical change in the cement.

Mr. Smith.

MR. J. AUGUSTINE SMITH.—We are carrying on a series of experiments with regard to the question of steam curing and believe that the investigation will be complete enough to warrant us in giving you the facts as we find them. The work has been carried on for about three years, and the experiments show that the theories, in regard to steam curing under pressure, as held in the past have been entirely erroneous. Using identical aggregates, the same proportion of cement, curing by sprinkling the blocks under the most exacting and perfect conditions, that is eight hours of each day for six months or 172 days, we obtained, by steam curing under pressure for two days, with one-half the quantity of cement, the same strength as by sprinkle curing under the conditions named.

In other words, using one part of cement to four parts of Merrimac sand we obtain a crushing strength of about 2,300 lbs. per sq. in., at 172 days, the blocks being sprinkled each day, eight hours of the twenty-four. With steam curing under pressure, using the same identical aggregates and the same amount of cement, *i. e.*, the same mixture, we get a crushing strength of 4,800 lbs. per square in. Using the same aggregates in the proportion of 1 to 8, we get a strength of about 2,180 lbs. per sq. in. or a little less than we secured with a 1 to 4 mixture under sprinkle curing for six months. The continuity of the strength of the stone has been demonstrated to our satisfaction. At one year it has shown a little greater strength than at two days.

Desiring, however, to be perfectly sure of our ground we do not care to present the above information in tabulated form, and will not until we are thoroughly satisfied as to the absolute correctness of our tests. I just wish to give you this information because the development of the concrete block is naturally dependent upon the ability of the manufacturer to make it the equal, or the superior of any other building material.

Mr. Frick. MR. G. F. FRICK.—I want to ask what pressure of steam, how many pounds pressure was used?

Mr. Smith. MR. SMITH.—The results as we found them were with a pressure of 140 lbs. per sq. in. as indicated by the steam gauge. The blocks were 24 hours old before entering the kiln, and were left there for 24 hours. Now then, the introduction of steam at that pressure must be done in a certain manner. We found that at 20 lbs. pressure we secured very little greater strength than with moist steam, and at 40 lbs. the advance was slight, but certain. At 80 lbs. the strength ran up tremendously and at 100 lbs. it was still greater. The maximum pressure we used was 120 lbs., but we were carrying our tests along so as to obtain results at 180 lbs. which we think is the pressure that should be used. Until our experiments prove this we do not wish to make a definite statement.

Mr. McCollough. MR. ERNEST MCCOLLOUGH.—I would like to ask as to the construction of the chamber to withstand such pressure, as to the number of blocks cured at one time and as to the period for which they are kept at that temperature.

Mr. Smith. MR. SMITH.—The chamber is constructed especially for this character of work and is of ¼ in. boiler iron of the best quality, fitted with a steel door, and it is, of course, a specially constructed kiln. The number of blocks is the number that will go in on a specially constructed car for the purpose. So far our experiments have been carried on with a small number of concrete specimens and we are now about to investigate the curing of blocks in large quantities. Those we have cured so far have been in individual lots, say 6 to 8.

The experiments were carried on under perfect scientific conditions. The aggregate is measured by weight, also the water and the consistency was, in point of moisture, all that the cement should have, plus the surplus necessary for extraordinary absorption by the atmosphere, that is to say about 8 to 10 per cent. of moisture was used.

Mr. Hutchens. MR. O. B. HUTCHENS.—I would like to ask the gentleman if any experiments with more than 8 per cent. of water have been made.

MR. SMITH.—I think we made some experiments with 10 per cent. We were testing for what has been called dry tamped blocks, which is, of course, a misnomer. We were testing tamped blocks and trying to arrive at the proficiency of steam curing in relation to that form. We did not attempt to try it out on poor blocks. Mr. Smith.

I would add that there is a great difficulty in using steam under pressure unless the kiln is prepared for it. We have been carefully gathering statistics with regard to exhaust steam, and it seems that no additional strength is obtained by curing a quantity of stone with exhaust steam. Pure acceleration is secured, that is the time necessary for complete curing is reduced from twenty-one to three or four days by the use of exhaust steam. If you withdraw the water from the moist steam, the exhaust steam, you will not secure as good results as with sprinkling the blocks. Steam curing is a matter that should be given very careful consideration, because it represents a development and an advance in the block industry that everybody will be able to take advantage of after the real facts are demonstrated.

MR. FEATHERSTONE.—I would like to make one suggestion on the subject of superheated steam, or rather steam under pressure, for creating additional strength, or bringing the strength of dry tamped concrete nearly to normal. Now it is well known that the dry mixture, not dry tamped mixture, but well graded and mixed concrete, during its forming will stand pressure from 3,400 to 3,500 lbs. per sq. in. It is very true that 2,300 lbs. is very high for a tamped block, many of which do stand but 600 or 800 lbs. pressure. If by a simpler method, either steam curing or moist atmosphere, we could use a much wetter aggregate it would be more efficient than first making a dry mixture, which is surely imperfect, and then using extreme means to increase the strength. By the latter method we still have the porosity which is the greatest evil of the concrete block. I think in steam curing we should consider a method for making a much better form of brick or block. The higher strength should be more easily attained than by first making the block dry and then attempting to cure it. Mr. Featherstone.

Mr. Smith. MR. SMITH.—On the question of making good blocks we have learned from our investigations that the greatest cause for poor blocks is the lack of the proper amount of water. When we claim to cure blocks afterwards by sprinkling, you cannot put the water there which was not in the block at the beginning. It is absolutely essential that sufficient water is added to the concrete to make it good to begin with. To make good blocks it is absolutely necessary to make a proper selection of the aggregates, to secure the least number of voids. Then there should be sufficient cement to fill the voids and sufficient water to crystallize the cement. There is, however, a mistaken idea with regard to the amount of water necessary. Experiments that have been carried on in Germany, a country that is as far ahead of us as we are ahead of some other countries in concrete, have demonstrated that the cement having exactly the amount of water necessary to crystallize it, and no more, makes the strongest concrete. The amount must be determined by the character of the aggregate; some take more, some take less. Some cement requires more water, some less. It is no easy matter to make good concrete blocks.

Mr. Ewing. MR. L. D. EWING.—I have been experimenting as to the proper amount of water since 1902 and have made blocks in which the moisture was so plenty that in tamping the mixture in the mold box, the water ran through, with no difficulty to get the block from the machine. This mixture seemed to set very well, but later experiments have shown that from 8 to 10 per cent. of water, with the proper aggregates, makes the densest and the strongest concrete block. We have worked on that theory this past season with good results.

GENERAL.

A Member. A MEMBER.—I have built two cement block silos this summer, 16 ft. outside diameter, 14 ft. 9 ins. inside diameter and 34 ft. high. I plastered them inside with cement mortar.

Mr. Bradley. MR. A. T. BRADLEY.—I think plastering is very necessary in order to keep the material, the ensilage, from coming through the joints after it begins working. I have heard of the joints

of silos being properly filled and the material oozing through later on and it is very necessary to plaster on the inside. **Mr. Bradley.**

A MEMBER.—I use wire about the size of a lead pencil every second course and make a half inch groove in the blocks about an inch from the face. **A Member.**

MR. WILLIAM J. GENTHER.—I would like to know if anyone has had trouble with end joints. Now in a great many blocks there is a 2 in. hollow space where they butt against the end. If the joint is perfectly straight through, many times you do not get the joint filled properly with mortar. If you are running a ¼ or ⅜ in. joint, it is very difficult to fill it. To overcome this trouble I have milled my machine about $^1/_{32}$ in. so as to form a wedge. Any time the mortar is pressed in there, no matter how tight the joint, you can fill it because you can wedge it in. I never find any difficulty in the mortar dropping out, should it not adhere to the end. **Mr. Genther.**

MR. GEORGE J. GILL.—I would like to ask whether in mixing the mortar hydrated or quicklime is used? **Mr. Gill.**

MR. BRADLEY.—Where the mortar is all cement, it appears to be set as quickly as the block is placed and you can do nothing with it. I use hydrated or quicklime, but only enough to keep the mortar soft. When a block is layed it is turned up, the mortar put on the end of the block and shoved up against the other block. We find that we can regulate the size of the joint much better. It is hard to keep the joints of the same size, and at the closure it is either too wide or too narrow. **Mr. Bradley.**

A MEMBER.—I find in laying blocks that if they are thoroughly saturated before being placed in the wall, with a 1-2 mixture of cement mortar, they can be very readily handled. I have had very good success this summer in placing such blocks. **A Member.**

MR. GENTHER.—On a large job you can saturate the blocks, but otherwise it is almost impossible to keep them all moist and there are some dry ones that will get in. In regard to the laying, I use a 1-3 mixture and about half a sack of hydrated lime to one sack of cement. The 1-2 mortar will work with certain sands, but not with all. There is a great deal of difference in sand from different localities and it has a great deal to do with the proportion of cement and lime. **Mr. Genther.**

TOPICAL DISCUSSION ON REINFORCED CONCRETE.

On Construction of a Concrete Dome.

Mr. Prince. Mr. George C. Prince.—I would like to ask whether it would be feasible to cover a dome of a church with solid concrete, the base being 72 ft. in diameter. We are at present covering it with slabs of concrete, perhaps 3 by 5 ft. or about that average in size. Of course, the size of the slabs naturally diminishes towards the top.

The style of architecture contemplated requires a dome almost hemispherical in shape, and we want to cover that dome all over with concrete. The present plan, according to our architects, has been to make the concrete in slabs with a rib in the top projecting upwards and a rib on the bottom on the next one above to hook over so as to form a water-tight joint. The perpendicular joints are then covered with a concrete cap setting over the upturned edges of these blocks. It occurs to me that with reinforced concrete the work can be done considerably cheaper and probably better, especially as to any leakage.

Mr. Lindau. Mr. A. E. Lindau.—A concrete dome of almost the same dimensions was built for the Naval Academy Chapel in Annapolis, and was about 8 ins. thick. It was a shell without ribs, just a hemispherical shell of concrete, reinforced with bars horizontally and vertically.

As far as computations on domes are concerned, they are in a very unsatisfactory state. There has been no theory advanced as far as I am aware, which takes into consideration the elastic properties of a material like concrete. All theories so far devised assume voussoir action, that is, a piling of one block upon the other, and the computations are merely confined to static action from a system of blocks of that kind. According to present theories the stresses are directly proportional to the thickness of the concrete or the unit load on the shell. In other words, it seems to make no difference how heavy or thin you make a concrete shell the stress on the bottom of the dome remains the same. The danger is that the shell may be so thin that the slightest

deviation of the pressure, from the center of any load, would put such stresses in the dome as to cause a rupture either in compression or tension. Mr. Lindau.

ON THE EFFECT OF GASES AND SMOKE ON CONCRETE.

MR. EMILE G. PERROT.—I would like to ask whether any data has been collected in regard to the effect of heat and smoke on reinforced concrete chimneys. In other words, is there any record of the durability of the oldest reinforced concrete chimneys that have been built in the United States? Mr. Perrot.

MR. SANFORD E. THOMPSON.—A recent examination of one of the oldest reinforced concrete chimneys, built in 1898, with a wet mixed concrete, showed it in very good condition except that there were four long vertical cracks at quarter points on the circumference. I do not know the exact amount of horizontal reinforcement, but if it is sufficient to take the shear these cracks are not dangerous structurally. An examination of the interior of the stack had been made a short time before my visit, and the concrete was found to be in perfect condition. The reports in nearly all cases upon the interiors of concrete chimneys are uniformly that the concrete is unaffected by the heat where the gases are of ordinary temperature. In one case where the gases were discharged into the chimney at an excessivly high temperature because of a blast, the concrete was injured. Of course to stand the stresses due to differences in temperature in the interior and exterior, the stack must be thoroughly reinforced horizontally as well as vertically. Durability and permanence depend upon both the design and the method of construction. Mr. Thompson.

A reinforced concrete chimney well designed should usually be cheaper than tile or brick construction and where the price is appreciably less I would recommend the concrete chimney from economic considerations.

MR. WALTER F. BALLINGER.—One objection that I have found to reinforced concrete chimneys is that they have to be laid up in a semi-dry state in order to move the forms the next day. This leaves a series of rings about 5 ft. high, and the shrinkage of the concrete in each separate ring makes quite a bad horizontal joint every 5 ft. The chimneys we have had Mr. Ballinger.

Mr. Ballinger. charge of have not been up long enough to show any ill effects. I have a fear that some day the water from the outside will get into the steel and combining with the sulphurous gases from the inside will cause the vertical steel bars to rust. This would leave so many rings set on top of each other and no tensile strength between them to resist the wind pressure. If it were possible to make the chimneys of sloppy, wet concrete, so that the cement would get all around the bars and thoroughly protect them, I would feel more in favor of it. One chimney we did build in that manner, and that is all.

Mr. Thompson. MR. THOMPSON.—I thoroughly agree on the point that a concrete chimney should be built with wet concrete, wet enough so that it will surround the steel and embed it at all points. This requires a mushy mix and it is perfectly practical to use this consistency.

With wet concrete it seems frequently necessary to allow the forms to remain for two days instead of one, and in some cases two sets of forms are used to accomplish this. Wet concrete is perfectly feasible in chimney construction, and at one plant work is to be started this spring on that basis, with very complete specifications requiring a concrete of the same consistency and proportions as is used in first-class building construction. With a dry mixed concrete, which results in a porous mass, there is poor adhesion to the steel, and I consider that there is serious danger of water penetrating to the steel and rusting it.

Mr. Andrews. MR. H. B. ANDREWS.—In building a 150 ft. stack in Norwich, Conn., three years ago, we used wet concrete with three sets of forms. We put in the concrete in the morning and moved the forms in the afternoon of the next day without any trouble. That chimney has been in existence three years and is in perfect condition, no cracks whatever showing in it and it has been very satisfactory.

Mr. Perrot. MR. PERROT.—I would like to ask Mr. Andrews—he built a chimney for us in Salem, Mass., of blocks—whether he has seen that chimney lately and whether any cracks have appeared in the blocks.

Mr. Andrews. MR. ANDREWS.—I had an opportunity of seeing that chimney about a month ago and the condition is the same as when it was

built, two years ago. There are a few cracks in the blocks which were there originally, I think, due to handling while green, but no further cracks have occurred, and none in the joints. That is, there may be a continuation of one or two joints of the cracks that developed in the blocks, but no long cracks. Mr. Andrews.

MR. A. E. LINDAU.—In answer to the question in regard to the effect of smoke and gases on concrete, it might be interesting to give some information I have received very recently from a lead-smelting company, on one of the largest reinforced concrete stacks that has been built. The information came from the general manager in answer to a question as to the condition of the chimney at this time. The chimney is being worked under very unusual conditions, not only having the ordinary flue gases, but having them very heavily laden with sulphurous gases which would have a more corroding influence than the ordinary chimney gases. I was informed in a letter about a month ago that the chimney on the last examination—it had been in service about three years then—was in perfect condition. He said nothing about cracks, but that they were thoroughly satisfied with the work. Mr. Lindau.

In regard to radial block chimneys, I recently saw one that had been built but a short time ago by an experienced firm and yet had a vertical crack for a considerable distance from the top. I understand that with expert workmen, such as they have in Germany, successful radial chimneys can be built.

MR. PERROT.—Answering the question of cracks, I think that can be overcome very largely by an independent core. We have built regular brick chimneys, that is, regular standard brick chimneys, reinforced concrete chimneys, steel stacks and all kinds. Now we have all heard of brick chimneys cracking, we have had concrete chimneys crack, we have had radial chimneys crack. So I think it is largely a question of design as well as of material and workmanship. For instance, I do not believe in building any kind of chimney, no matter what it is, without an independent lining that can be taken down and replaced the same as in furnaces. I believe that anything in contact with heat should be made of some material that is refractory in its nature and made in such sizes as are easily taken down and replaced. I do not believe Mr. Perrot.

Mr. Perrot. in lining a reinforced concrete chimney with reinforced concrete. If you ever want to reline it there will be trouble, because to take down the reinforced lining would be a difficult job. I believe in lining a reinforced concrete chimney with some kind of plastic material, say asbestos cement, on wire lath, leaving an air space between the chimney and the lining, or else lining it with brick or something that is in small units and can be taken down.

Furthermore, in regard to the cracks in radial brick chimneys, we find that a radial brick chimney will crack if not lined with a core one-third of its height. I do not believe that it is possible to build a radial brick chimney, to-day, without a core to keep it from cracking. The Pennsylvania Railroad Company has a large concrete chimney without a core in Philadelphia, which is banded about every 6 ft. from top to bottom, due to the fact that it cracked. It is at the car shops where wood and shavings are burned in a return tubular boiler, and the heat from the wood is so great as to cause an expansion and contraction sufficient to create trouble. I do not care what chimney you build, you will have to put a core or lining in it.

We have one building in which we put a Webber chimney, which has no air-space or lining. The chimney would be better if lined so as to prevent the scouring action of the heat as the flames strike the concrete and weaken the chimney. If the scouring action affects the lining, it can be taken out and replaced. In that way you will protect the exterior of the concrete shell which supports the chimney. I would not build a chimney and subject the structural parts to extreme changes of temperature. I think there should be a lining independent of the stack, so it can be replaced.

Mr. Thompson. MR. THOMPSON.—The heat from an ordinary boiler is usually not over 300 to 500 degrees F. It is somewhat remarkable that the temperature varies so little between the bottom and the top of the stack, the heat being very nearly as great three-fourths of the way from the bottom as it is close to the bottom. A temperature of 500 degrees F. is not too high for concrete, as has been shown by frequent tests, and there is a question as to the positive necessity of a lining for a concrete chimney, although

I consider it advisable to use one in the lower part of the stack, so that if the flame impinges on the concrete the principal shell will be protected. In any case there should be a good percentage of horizontal reinforcement, preferably spaced quite close together, using bars of small size. Mr. Thompson.

MR. ANDREWS.—I would like to ask Mr. Perrot if he would line a concrete chimney in which the flue gases go through an economizer, where the temperature probably would not be over 250 degrees. It requires a temperature of some 600 degrees to dehydrate concrete, and if it is not dehydrated I do not think it deteriorates. Mr. Andrews.

MR. PERROT.—My purpose in any engineering proposition is safety and I believe a chimney is an important structure and one which cannot be inspected daily. Economizer temperatures are lower than those of ordinary flue gases. I do not doubt in the least that a chimney is all right with 200 or 600 degrees temperature, but there is also the question of longevity. I would line only about 200 ft. from the bottom, or in general a small percentage of the height, say one-third. Mr. Perrot.

MR. BALLINGER.—We had an experience, about twelve years ago, with a big brick chimney which might throw some little light on the subject. It was before radial brick or concrete chimneys were popular in this country. This particular chimney was about 150 ft. high and we wanted to make it very good. We had 26 in. walls in the octagonal base, and a 4 in. brick lining or core, supported by header brick projecting into it at intervals around the chimney. In about a year cracks appeared on three sides of the base of the chimney, and on investigation we found that the brick lining had partly broken down. About two or three bushels of bricks of the lining were taken out of the bottom of the chimney. There was no opening to let the outside air into the space between the core or lining and the stack proper, this space being about 2 ins. wide. So we had holes about 8 x 10 ins. cut into the chimney from the outside to this air space and put in registers. We then pasted paper over the cracks to ascertain whether they would extend any further, which they did not. The admission of outside air between the core and the stack prevented further expansion and contraction. I think this was Mr. Ballinger.

Mr. Ballinger. a case where the walls were too thick; making too great a difference in temperature between the outside and the inside of the wall. I believe this was largely responsible for the cracks and the same thing would be true in a concrete chimney. If there is no lining used, the great difference in temperature between the outside and the inside would probably cause cracks, or have a tendency to, even though the chimney were well built.

Mr. Anderson. MR. W. P. ANDERSON.—I have heard a good many railroad engineers object to concrete for the roof of roundhouses on the ground that the smoke from the engines affected the concrete. Has anyone had any experience in that line? I know that there is prejudice against using concrete, at least on the part of some railroad engineers, for the top of roundhouses.

Mr. Lindau. MR. LINDAU.—In the matter of the deterioration of concrete due to gases of various kinds a series of experiments were carried out in Germany at the testing establishment in Grosslichterfelde. It was on this very question of corrosion of reinforcement in concrete due to gases in the air or chimneys, such as CO and CO_2. The experiments were carried out on beams that had been tested previously as to their use particularly for this purpose. They were tested under a load that developed, say 16,000 to 18,000 lbs. per sq. in. in the steel, so as to cause the incipient cracks appearing at about that stress, or before. An arrangement was made whereby the gas was generated and conveyed by means of rubber tubing to a metal envelope placed in the middle of the beam and sealed so that the gases would act directly on the edge of said beam. The load was arranged so that the gases would come in contact with the beam at various loads for a day or two at a time. The result was that there was no effect noticeable either in the strength of the concrete or in the corrosion of steel in any of these beams in which the stress in the steel did not reach the elastic limit. In other words, the beams had to be loaded up to a point beyond the elastic limit to affect the steel.

Mr. Perrot. MR. PERROT.—In Philadelphia the authorities have seen fit to cover the plate girders forming the bridges which span the railroads with concrete, in order to protect the steel from the corroding action of the smoke. The city has also built reinforced concrete railroad arches.

MR. ANDREWS.—The city of Boston is also adopting concrete to protect their buildings where they are exposed to flue gases from locomotives. Mr. Andrews.

MR. THOMPSON.—Combustion is probably less perfect in locomotive boilers than in other boilers, and it is probable that the gas from them would be more injurious to the concrete than gas from the latter. The fact that concrete is used as a protection from locomotive gases, and, in fact, as a protection from gases of various kinds, indicates that in most cases no danger need be expected where the concrete is properly laid. Certain fumes are, however, quite injurious. I noticed not long ago an interesting case of deterioration of concrete due to animal fat, in a concrete building occupied by a lard manufacturing firm. Fumes from the boiling fat impinged upon the concrete roof and completely disintegrated it. The walls of the same building were unaffected where the fumes did not come directly in contact with them. Mr. Thompson.

ON METHODS OF MEASURING CONCRETE WORK.

MR. W. P. ANDERSON.—We had a contract at unit prices on concrete for floor finishing per sq. ft., so much a sq. ft. for form work exposed to concrete, so much a cu. ft. for concrete, so much a lb. for steel. When we came to settle up there was a dispute as to how these quantities were to be figured, amounting to about $2,500 or $3,000. We always have figured without deducting for openings, for instance, as the number of sq. ft. of floor surface, we take the area of the surface covered. We make no deduction for a column, because there is more expense working around it. The same thing applies to form work; if there was a radiator or a little hole in the concrete work, we had more additional cost in the form work because we had to build it just the same, and in addition a frame around the opening to keep the concrete out. When we came to figure up the quantities, the owner deducted for all these things, deducted for every place where we put in an angle iron on the floor. Angle irons were used in some expansion joints and a little space left between them. We had to deduct for the angle irons because there was no finish there. It got to a point where we sued, but in preference Mr. Anderson.

Mr. Anderson. to having an expensive litigation, which would have cost us more than $2,500, we stopped the suit and swallowed our loss. The owner held some of our money back which we wanted, while I think we could have established our rights in court, the expense of the suit would probably have been more than the amount involved.

Now I would suggest that some standard be adopted for concrete. There are standards in different sections for brick work; and other trades. If a specification is drawn and it is not mentioned in that specification definitely how the work is to be estimated, and if it is brick work and done by the thousand or at a unit price, the custom goes. Now the owners claimed, in the case I referred to, that reinforced concrete had not been used enough and there was no universal practice that we could absolutely prove. I would suggest that we adopt some method for figuring those things so that when the architect lets a contract and the specifications do not definitely state how the units shall be figured, there will be something to fall back on in case of a dispute.

Mr. Schuyler. MR. JOHN P. SCHUYLER.—I am very glad this question was brought up. I put down a walk for a contractor and there was a curb on each side of that walk, 6 ins. thick. The contract called for the walk to be 15 ft. wide. The curb set right under the walk and extended into the ground 2 ft. There was nothing said as to how the walk was to be measured when I took the contract, which called for the walk to be 15 ft. wide. When the walk was measured for the contractor, it was claimed that the curb was 6 ins. wide on each side, leaving the walk only 14 ft. wide. The curbing is paid for by the linear foot. Now that would make about 400 ft. difference with me and I would like to know whether it is right or wrong.

ON TEST OF A CONCRETE FLOOR DUE TO AN ACCIDENT.

Mr. Parsons. MR. O. B. PARSONS.—In supervising the concrete construction for the Adjutant General's Department of Ohio at Camp Perry, we had an experience in the way of an accident, which I believe to be of interest and possibly of benefit to many members of this Association, inasmuch as it demonstrates the actual

efficiency of reinforced concrete floors in withstanding not only heavy loads, but also extraordinary shocks. **Mr. Parsons**

During the erection of the large Mess Hall, a misplaced guy line caused five of the steel roof trusses spanning 76 ft. and weighing about 12 tons, to fall from their respective places in the roof to the second floor, an average distance of 21 ft., thus subjecting the floor to the severest test of which I have any record of a floor withstanding without material damage to the same.

In this case the only damage to the floor is illustrated in

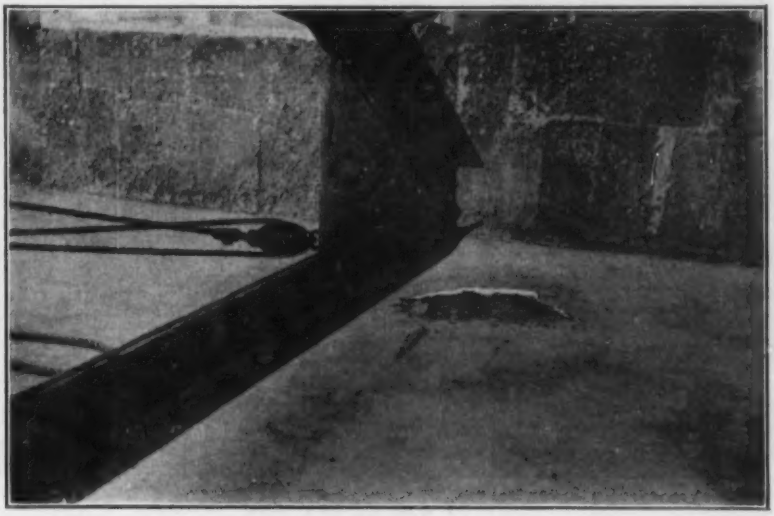

FIG. 1.—DAMAGE TO FLOOR BY FALLING OF STEEL ROOF TRUSS.

Fig. 1, which plainly shows it to be almost too insignificant to bear mentioning. With the steel trusses it was decidedly different; nine of the chords consisting of steel angles 5 x 3 x ⅜ ins., in pairs, snapped off as though they were of pine.

Fig. 2 shows one of the trusses that fell. It is a Pratt truss coming under the sloping ends of a hipped roof and buckled in the center until it dropped out of its pockets and fell unobstructed to the floor taking with it another 76 ft. truss of the Fink type and three half trusses, 20 ft. long, connecting it with the end wall.

Mr. Parsons. Fig. 3 is a photograph of approximately 12 tons of steel taken about ten minutes after it fell upon a concrete floor less than 90 days old, and which had been looked upon during the National Shoot by many who are as yet unfamiliar with the resisting qualities of reinforced concrete, and pronounced inadequate to support a crowd of people.

This floor was constructed by molding slabs in the field, 3 ft. wide, 14 ft. 7 ins. long, and 2½ ins. thick, reinforced with ¼ in. twisted steel bars at intervals of 4 ins. running both ways and pro-

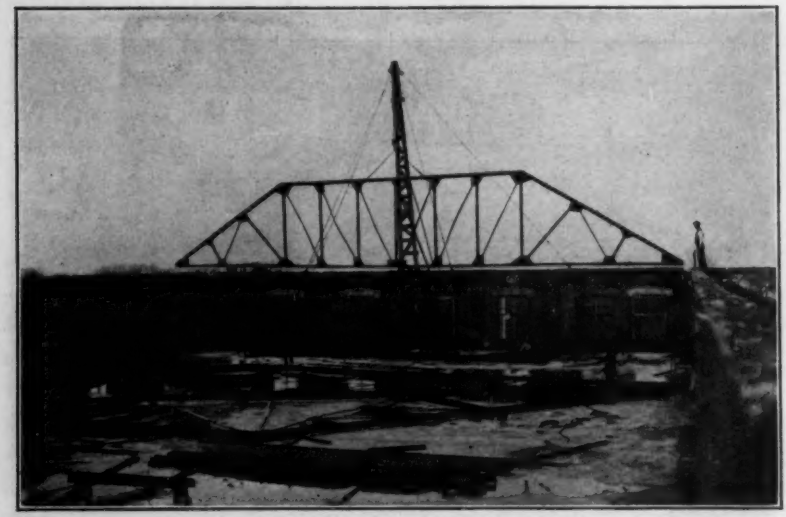

FIG. 2.—VIEW OF ONE OF THE ROOF TRUSSES.

jecting 6 ins. all around the slab. These slabs were then placed upon the girders with the projecting steel overlapping. A ⅞ in. board was then placed underneath and the seams poured, after which 3 ins. more concrete and a ½ in. top dressing was spread over all, making a total thickness of 6 ins.

The girders are 8 x 12 ins., reinforced with twenty-one ¼ in. twisted bars, and are supported at their intersection by 8 x 8 in. columns which are so spaced as to make the floor panels 15 ft. 4 ins. by 20 ft. respectively. The columns were reinforced with four ⅞ in. twisted bars hooped with No. 8 wire.

The concrete used throughout was a 1-2-4 stone mixture and any skimping that may have been done was with the sand and stone, good measure predominating in the use of cement. Mr. Parsons.

This method of floor construction is not always economical in dispensing with false-work, but its greatest merit in my estimation, is the combined strength of the concrete and steel which is obtained by the steel in the slabs which form the bottom or tension chord of the floor, being brought in tension by means of

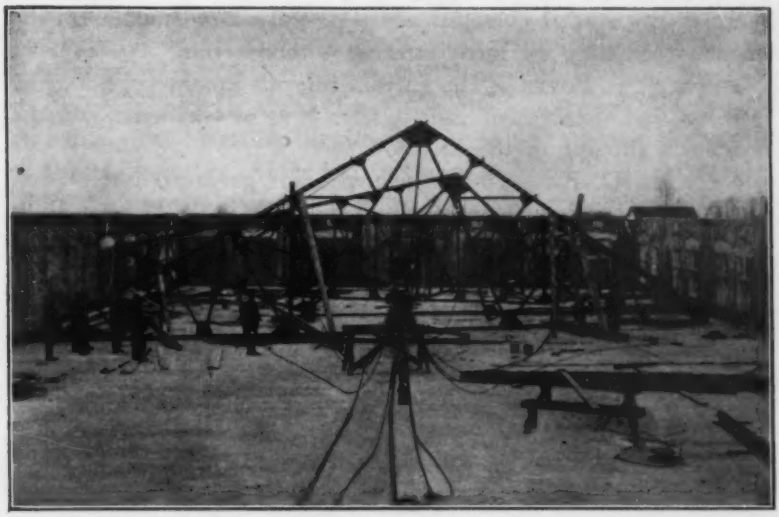

FIG. 3.—VIEW OF STEEL TRUSSES AFTER THE FALL.

supporting not only their own weight, but also that of the mixture which forms the top or compression chord before the latter has set. Whereas it is supported in a loose manner upon false-work until the concrete has become set, the deflection which must necessarily take place before any tensile stress is brought to bear upon the steel, will have cracked the concrete leaving only the tensile strength of the steel available for support.

In constructing a floor even in this manner, I would advise everyone not to use this test as a base upon which to estimate the strength of their floor unless the liberal use of good Portland

Mr. Parsons. cement, clean sand and thorough mixing are adhered to in the strictest possible manner.

ON GALVANIZED REINFORCEMENT.

Mr. Dougherty. MR. G. M. DOUGHERTY.—On the subject of galvanized reinforcing there seems to be a question as to whether galvanizing the reinforcement does not make it more subject to corrosion. I have noticed that a galvanized staple placed in a post near the surface, is very subject to corrosion. Does anyone know whether there is any special chemical action in galvanized metals on the inside, when they are fairly covered with concrete?

Mr. Boyer. MR. S. F. BOYER.—The galvanizing fills up the pores on the iron, so that the cement cannot take hold of the wire, and the result is a slipping of the wire.

Mr. Ewing. MR. L. D. EWING.—In the matter of galvanized steel surrounded by concrete, I am not very familiar with the protection given the steel and therefore unable to make any remarks about its lasting quality, but, in my experience as a contractor and builder in handling galvanized steel material, I have found that steel is very apt to corrode under the galvanizing. Hence, the concrete not coming into direct contact with the steel would not protect it against corrosion, and if rust should form under the galvanizing, the strength of the steel would be affected.

REPORT OF THE EXECUTIVE BOARD

FOR THE

YEAR ENDING DECEMBER 31, 1908.

Object of the Association.—We cannot emphasize too strongly the fact that this Association is primarily an educational institution, that it is not a commercial organization and that the exhibition which is coincident with the convention, permits a practical demonstration of many of the subjects under discussion at the Convention. Since the Association is not of a commercial character, we are dependent, in addition to the membership dues, on the revenue derived from the sale of space and from the nominal admission fees to the exhibition for the support of the Association.

Meetings.—While but two meetings of the Executive Board have been held during the year there have been, however, a number of meetings of its Executive Committee. This has resulted in a very large saving in the traveling expenses for the Executive Board meetings. It can be readily seen that with a large Executive Board, whose members are located at great distances from each other, the expense of a meeting would be so great as to make it practically prohibitive with our present sources of income. This demonstrates the wisdom of the amendment to the By-Laws made at the last Convention providing for an Executive Committee of the Board, whose duty shall be to attend to the business of the Association, during the intervals between Executive Board meetings.

The difficulties in securing a suitable place wherein to hold this Convention and Exhibition, the fifth annual, have been as great as in previous years. It will be seen from the minutes of the Executive Board that three different places other than Cleveland were considered, before the final location was determined, and the selection of a suitable location becomes each year a problem of greater difficulty with the demands for increased facilities.

Annual Statement of the Treasurer.

RECEIPTS.

Balance, January 1, 1908		$1,731 56	
Dues	$1,865 00		
Dues, Contributing Members	800 00		
Publications, sales and advertising	1,329 40		
Convention	72 25		
Interest	51 84		
Miscellaneous	9 20		
Exhibition, Buffalo	6,650 67		
Receipts for the Year 1908	$10,778 36		
Exhibition, Cleveland, 1909 (Collected in 1908)	2,912 50		
Total Receipts		$13,690 86	
			$15,422 42

EXPENDITURES.

Salaries	$1,533 08		
Rent	175 00		
Postage, Printing, Stationery, etc.	763 98		
Office Equipment	237 00		
Meetings, Executive Board	483 67		
Publications	2,209 37		
Convention, Buffalo	608 36		
Exhibition, Buffalo	4,848 89		
Miscellaneous	14 26		
Expenditures for Year 1908		$10,873 61	
Convention, Cleveland, 1909 (Paid in 1908)	$217 25		
Exhibition, Cleveland, 1909 (Paid in 1908)	293 33		
Honorarium, R. L. Humphrey, President, (Page 539, Volume V)	800 00		
		1,310 58	
Total Expenditures		$12,184 19	
Balance, December 31, 1908		3,238 23	
			$15,422 42

PHILADELPHIA, 22d September, 1909.

We hereby certify that we have audited the accounts of the Treasurer of the National Association of Cement Users for the year ended 31st December, 1908, and found that the dues collected as per the membership records and receipts from sales of Publications, etc., have been properly accounted for, that the disbursements were substantiated by vouchers and the accounts otherwise correctly kept.

The foregoing report of the Treasurer is in agreement with the books of account.

(Signed) LYBRAND, ROSS BROS. AND MONTGOMERY.
Certified Public Accountants.

The above statement of the Treasurer speaks for itself, and indicates the continued conservative policy of the Executive Board. The expenses increase with the growth of the Association. The preparation of standard specifications, etc., require the expenditure of larger sums than heretofore, and for this reason we have felt it incumbent upon us, in providing for the best interests of the Association, to do all of this work in a thorough manner, and are glad to note that our increased income over last year, has been almost sufficient to meet these new and larger expenses.

Proceedings.—The establishment of permanent headquarters has made it possible to issue the Proceedings of the last Convention much earlier than heretofore. These Proceedings, exclusive of advertisements, contain 418 pages of printed matter and illustrations; the latter are much more comprehensive than heretofore and the Proceedings have met the general approval of the members and others.

The revenue thus far derived from the advertisements in the Proceedings is not sufficient to cover the cost of publication, but future sales will probably offset this, and may eventually yield a profit.

Headquarters.—Pursuant to the action taken at the Buffalo Convention, the headquarters of the Association were established at Philadelphia in the month of May, 1908. An assistant to the President was secured and clerical force employed for carrying on the detail work of the Association. The attendance of the Assistant to the President greatly facilitated the opening of the Exhibition and the handling of the details of the Exhibition and

Convention. We believe that with the experience thus gained the work at the next Convention will be handled with still greater ease.

Exhibition.—We believe that the members who have attended previous conventions will recognize that this exhibition is a step in advance of those preceding. This is shown in many ways, notably in the artistic arrangement of the booths and the attractive display of exhibits. The exhibit spaces are the same size as those at Buffalo, but the Armory is smaller and the width of the aisles was reduced.

It is gratifying to refer to the fact that long before the opening of the Convention, all of the floor space had been sold, and a considerable number of exhibitors had overflowed to the gallery, which indicates the interest of the exhibitors in the work of the Association.

Contributing Members.—The importance of a fund derived from contributing memberships providing additional income, is self-evident. Those who are interested commercially in the industries the Association represents, will recognize the benefits resulting from its educational work and should aid by becoming liberal contributors to the Association. As a matter of fact, we are limited to increases in revenue to practically two sources—contributing and regular membership dues.

Amendments.—The Executive Board suggests the following amendments to the By-Laws:

Amend Article 1 by inserting after Section 2 a new Section 3, and renumbering the remaining sections.

SECTION 3. Any member contributing annually twenty or more dollars in addition to the regular dues shall be designated and listed as a Contributing Member.

Amend Article I, old Section 3, by striking out all after the first sentence and inserting the following:

The Secretary shall submit monthly to each member of the Executive Board for letter ballot a list of all applicants for membership on hand at that time with a statement of the qualifications, and a two-thirds majority of the members of the Executive Board shall be necessary to an election.

Insert after Article IV a new Article V, as follows:*

SECTION 1. Proposed Standard Specifications to be submitted at the Annual Convention by a Sectional Committee, and as amended and approved, passed to letter ballot which shall be canvassed within sixty days thereafter. A majority of the votes, of not less than ten per cent. of the total membership, shall be necessary for adoption.

Our President.—The Executive Board desires to take this opportunity to direct the attention of the members of the Association to the efforts of its President, Mr. Richard L. Humphrey. The success of the Association, its convention and exhibition, is largely due to him and his personal efforts. Few of us perhaps appreciate the vast amount of detail work in connection with the editing and publishing of the Proceedings and Bulletins and the management of the Convention and Exhibition.

We know that the results he has accomplished have been at great sacrifice of his time and strength, and it is with pleasure we record in this manner our appreciation of his work.

The Future of the Association.—It is the opinion of the Executive Board that if we adhere to the principles thus far enunciated as those of our Association, we shall have continued prosperity, and it is a pleasure to us to know that notwithstanding the depression of the last year, the Association has thrived. With the return of prosperity, are we too optimistic in suggesting that the year to come will be the largest and best of the Association?

We congratulate you upon the success thus far obtained and look forward to the future with full confidence.

Respectfully submitted on behalf of the Executive Board.

MERRILL WATSON,
M. S. DANIELS,
Committee to Prepare Annual Report.

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* This new Article V was amended at the Convention to read as follows

SECTION 1.—Proposed Standard Specifications to be submitted to the Association must be mailed to the members at least thirty days prior to the Annual Convention, and as amended and approved, passed to letter ballot which shall be canvassed within sixty days thereafter, such specifications shall be considered adopted unless at least ten per cent. of the total membership shall vote in the negative.—ED.

MINUTES OF MEETINGS OF THE EXECUTIVE BOARD.

Board Meeting Held May 25, 1908, House of the American Society of Civil Engineers, New York, N. Y.

Present: Richard L. Humphrey, President; Merrill Watson, M. S. Daniels, George C. Walters, A. T. Bradley, E. S. Larned, Charles D. Watson and W. W. Schouler, Vice-Presidents; George C. Wright, Secretary; H. C. Turner, Treasurer.

The minutes of the last meeting held on January 20 were read and approved.

The President reported that he had transmitted a voucher for $100.00 to Mr. W. W. Curtis as instructed and read a letter from Mr. Curtis declining to accept the voucher. After discussion the President was instructed to make settlement with Mr. Curtis.

On motion, the President and Mr. Charles D. Watson were empowered to engage legal assistance in case of failure of negotiations to settle a claim against the Chamber of Commerce of the City of Buffalo in the matter of the payment of a bill for light, heat and janitor services at the Exhibition.

The statement of Mr. Dai H. Lewis, manager of the Buffalo Convention, was presented, and on action, the Secretary and Treasurer were instructed to audit the accounts of Mr. Lewis and to take whatever steps necessary to release his bond.

Motion was made and seconded that each advertiser in the Proceedings for 1908 receive one copy of the volume for each $10.00, or fraction thereof, of advertising.

On motion, the President was authorized to have the text of the Proceedings electrotyped, such electrotypes to be the property of the Association.

The place for the next Convention was then discussed, and, on motion, referred to the Executive Committee with the recommendation that Louisville, Ky., should satisfactory arrangements

be made, be chosen, provided that due consideration be given to Pittsburg should it offer satisfactory facilities within sixty days; and in the event of both cities being unable to provide the necessary facilities, the offer of Atlantic City be accepted.

The following resolution, submitted in writing by Mr. Sanford E. Thompson, was on motion accepted. A copy of this resolution to be mailed to each committee chairman.

All reports of committees which contain suggested specifications shall be submitted to the Executive Board before presentation to the Association, and copies of such reports shall be mailed to each member of the Executive Board for criticisms and suggestions. Criticisms and suggestions made by the members of the Board shall be sent to the Board and also to the chairman of the special committee making the report, for consideration. In case they are not adopted by this committee the Executive Board may request their presentation to the Association as suggested amendments to the committee report.

No committee report shall be given to the press or published for distribution except to the members of the Association, until formally adopted by the Association, and if in any case such reports are mailed in advance to the members of the Association, they shall be distinctly labelled as not being for publication.

The President was authorized to prepare a pamphlet containing a list of members, officers, committees, charter, by-laws and a short history of the Association; also to issue separate reprints of all standard specifications adopted by the Association.

The President was authorized to open suitable headquarters for the Association at Philadelphia.

The action of the President in engaging Mr. Edward E. Krauss as assistant was approved.

The President was instructed to communicate with those members who had been refused 1½ fares to the last Convention stating the conditions.

On motion, it was decided to segregate the working and non-working exhibits at the next convention.

The Treasurer submitted his report which was approved.

In pursuance of the resolution of the Association at the last Convention, the Board authorized the Treasurer to pay the President the sum of $800.00 to reimburse him for all expenses to the close of the 1908 Convention.

The meeting then adjourned.

COMMITTEE MEETING HELD JUNE 25, 1908, HOTEL TRAYMORE, ATLANTIC CITY, N. J.

Present: Richard L. Humphrey, President; H. C. Turner, Treasurer; Merrill Watson and M. S. Daniels, members of the Executive Committee.

The question of the place for the next Convention was thoroughly discussed and Young's New Million Dollar Pier offered by Atlantic City for the purposes of the Convention was visited and the meeting again resumed at the Hotel Traymore.

It was decided to adjourn to meet at the call of the President. In the meantime an endeavor to be made to secure some proposition from the City of Pittsburg, Pa., and a more definite proposition from the City of Louisville. In the absence of this information and the importance of the location of the next Convention, the Executive Committee did not deem it expedient to reach a definite decision at this time.

Adjournment.

COMMITTEE MEETING HELD JULY 14, 1908, OFFICE OF TURNER CONSTRUCTION COMPANY, NEW YORK, N. Y.

Present: Richard L. Humphrey, President; H. C. Turner, Treasurer; Merrill Watson and M. S. Daniels, members of the Executive Committee.

The Executive Committee continued its deliberations concerning the place for the next convention, and after carefully considering the facilities offered by Pittsburg, Louisville and Atlantic City the following resolution was adopted.

Resolved, That the President be authorized to enter into negotiations with the City of Louisville as a place for the next Convention, provided that the detailed arrangements are satisfactory to the President, and that in addition to the Exhibition and Convention halls and headquarters, the City of Louisville contribute $1,000.00 to the expenses of the Convention. Failing to accomplish this the President be authorized to select Atlantic City, upon arrangements of satisfactory terms.

Adjournment.

COMMITTEE MEETING HELD SEPTEMBER 24, 1908, OFFICE OF TURNER CONSTRUCTION COMPANY, NEW YORK, N. Y.

Present: Richard L. Humphrey, President; H. C. Turner, Treasurer; and M. S. Daniels, member of the Executive Committee.

The question of the place for the next Convention received very careful attention and it was decided to await the action of the Fiscal Court in Louisville before making any final decision in the matter. It was further decided to have a meeting of the Executive Board immediately after the decision of the court is received.

The discharge of the bond of Mr. Dai H. Lewis was approved.

The Executive Committee decided that all matters pertaining to the work of the Publicity Committee, such as notices to be sent out, should receive the approval of the President before being published. It was also decided that wherever the various standing committees desired to issue circulars to outside sources that this work be done through the Philadelphia office.

The proposition to allow 10 per cent. discount to libraries and dealers on prices of publications when requested, was agreed to.

The meeting adjourned to meet at the call of the President.

BOARD MEETING HELD OCTOBER 12, 1908, HOUSE OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS, NEW YORK, N. Y.

Present: Richard L. Humphrey, President; George C. Wright, Secretary; H. C. Turner, Treasurer; and W. W. Schouler, George C. Walters, E. S. Larned, Merrill Watson, and Charles D. Watson, members of the Executive Board.

The minutes of the meeting of the Board of May 25 were adopted as read.

The minutes of the meetings of the Executive Committee on June 25, July 14, and September 24 were adopted as read and the action taken approved.

The report of the Treasurer was approved as read.

The report of the committee on the auditing of accounts of Mr. D. H. Lewis, manager of the Fourth Exhibition, was approved as read.

The President was authorized to take the legal steps necessary to collect the claim against the Chamber of Commerce of the City of Buffalo.

The President was instructed to write a letter of acknowledgment to Mr. D. H. Lewis, manager of the Fourth Exhibition, thanking him for his services.

The question of contributing membership was taken up and it was decided to recommend at the next Convention the following amendment to the By-Laws:

Amend Article I by inserting after Section 2 a new Section 3, and renumbering the remaining sections.

SECTION 3. Any person contributing twenty or more dollars in addition to the regular dues shall be designated and listed as a contributing member.

It was decided to recommend to the next Convention an amendment to the By-Laws governing the adoption of Standard Specifications as follows:

Insert after Article IV a new Article V as follows:

SECTION 1. Proposed Standard Specifications shall be submitted at the Annual Convention by a Sectional Committee, and as amended and approved, passed to letter ballot which shall be canvassed within sixty days thereafter. Such specifications shall be considered adopted unless a majority of the total membership shall vote in the negative.

In order to facilitate the work of the Association, it was decided to recommend the following amendment to the By-Laws governing the election of new members:

Amend Article I (Old Section 3), by striking out all after the first sentence and inserting the following:

The Secretary shall submit monthly to each member of the Executive Board for letter ballot a list of all applicants for membership on hand at the time with a statement of the qualifications, and a two-thirds majority of the Executive Board shall be necessary to an election.

On motion, it was decided to adopt the new form of application blank for membership as presented by the President.

The President presented a list of the applicants for membership received since the last meeting, and on motion their election was approved.

It was decided that new members joining after November first shall have their dues charged as of the succeeding year.

The Committee on Contributing Membership presented a report of progress which was approved.

The question of the management of the next Exhibition was considered and it was decided that the Assistant to the President give bond to the extent of $5,000, premium on the bond to be paid by the Association.

The President was instructed to appoint a committee to consider the question of local associations and to report at the next meeting.

On motion it was decided to allow the Committee on Art and Architecture a sum not exceeding $70.00 to cover expenses in the preparation of their report.

The action of the President in issuing monthly circulars was approved.

After a discussion as to the location of the next Convention it was decided to appoint a committee consisting of the President and Charles D. Watson, with full power.

It was decided that all authors of papers presented at the Annual Convention be entitled to fifty reprints.

The Board considered the question of annual reports of Sectional Committees and decided to require all reports to be in the hands of the President by December 15, and that copies of such reports be furnished to the members of the Board within one week.

The President presented the rules and regulations governing the Exhibition and the form of contract, which were approved.

Adjournment.

COMMITTEE MEETING HELD DECEMBER 14, 1908, HOTEL VICTORIA, NEW YORK, N. Y.

Present: Richard L. Humphrey, President; H. C. Turner, Treasurer; Merrill Watson and M. S. Daniels, members of the Executive Committee.

The Committee considered matters connected with the Fifth Annual Convention and Exhibition, and approved the suggestion of the President to award prizes for the most effective, artistic

and attractive exhibits. One hundred dollars was allotted for this purpose, to be divided as follows:

1st Prize	$50.00
2nd "	25.00
3rd "	15.00
4th "	10.00

It was tentatively agreed that a certificate of such award be given in addition to the cash prize.

It was decided to provide music in the exhibition hall on Monday and Saturday.

The Committee considered the question of passes, and agreed to the plan to issue passes to the members of regiments having headquarters in the Armory, also to the exhibitors and their attendants; such passes to be used as provided for in the rules governing the Exhibition. An invitation card to be printed. These invitations to be printed with the name of the exhibitor and in such quantities as desired. Tickets to be issued to exhibitors at the rates fixed in the rules, it being understood that these tickets must be paid for in full by the exhibitor which will be debited to the ticket account column and a refund made after the exhibition for those tickets which were not used.

BOARD MEETING HELD JANUARY 11, 1909, 2 P. M., HOTEL HOLLENDEN, CLEVELAND, OHIO.

Present: Richard L. Humphrey, President; George C. Wright, Secretary; and Merrill Watson, M. S. Daniels, George C. Walters, W. W. Schouler, members of the Executive Board, and Albert Moyer, Secretary of the Committee on Art and Architecture, representing Mr. Charles D. Watson, Chairman of that Committee.

The minutes of the meeting of the Executive Board held on October 12, and the meeting of the Executive Committee held on December 14, 1908, were approved as read.

It was decided to appoint a committee consisting of the First Vice-President, Mr. Merrill Watson, and the Second Vice-President, Mr. M. S. Daniels, to prepare the Annual Report of the Executive Board.

The President was instructed to appoint a committee of three to decide on the award of prizes as to the most attractive, effective and artistic arrangement of exhibits.

It was decided to create the following Sectional Committees for the year 1909:

Art and Architecture,
Building Laws and Insurance,
Machinery and Appliances,
Concrete and Reinforced Concrete,
Roadways, Sidewalks and Floors,
Specifications for Cement Products.

The question of allotting free passes to subscribers to the local fund was discussed and it was decided that they receive one pass for each $5.00 subscribed; the same to apply to contributing members.

It was the sense of the Board that each exhibitor be allowed passes for qualified attendants to the extent of two passes for each space taken.

Adjournment until 9.30 P. M.

BOARD MEETING HELD JANUARY 11, 1909, 9.30 P. M., HOTEL HOLLENDEN, CLEVELAND, OHIO.

Present: Richard L. Humphrey, President; George C. Wright, Secretary; H. C. Turner, Treasurer; and Merrill Watson, George C. Walters, M. S. Daniels, W. W. Schouler, members of the Executive Board, and Albert Moyer, representing Charles D. Watson.

On motion, the President was instructed to appoint a committee to audit the report of the Treasurer. The President appointed Mr. Merrill Watson and Mr. M. S. Daniels.

After discussion it was decided that Thursday evening, which had been set aside for entertainment, be devoted, from 8 to 10 P. M., to the reading and discussion of papers and that after 10 P. M. an informal reception be held.

It was decided that the following additional Sectional Committees be created:

Exterior Treatment of Concrete Surfaces,
Specifications for Fireproofing.

On motion the following Nominating Committee on new officers was appointed:

E. D. Boyer, Catasauqua, Pa., *Chairman.*
J. E. Conzelman, St. Louis, Mo.
O. U. Miracle, Minneapolis, Minn.
B. H. Rader, Pittsburg, Pa.
George Taylor, Boston, Mass.

It was decided that it is the sense of the Executive Board that the Nominating Committee should consider only the best interests of the Association in making its report.

On motion the Committee on Resolutions was appointed as follows:

W. C. Boynton, Detroit, Mich., *Chairman.*
J. B. Foote, Chicago, Ill.
F. D. Leslie, Cleveland, Ohio.
Emile G. Perrot, Philadelphia, Pa.
J. P. H. Perry, New York, N. Y.

The amendment to the By-Laws covering the adoption of Standard Specifications referred back to the Board was considered and revised to read as follows:

Insert after Article IV a new Article V as follows:

SECTION 1. Proposed Standard Specifications to be submitted to the Association must be mailed to the members at least thirty days prior to the Annual Convention, and as amended and approved, passed to letter ballot which shall be canvassed within sixty days thereafter, such specifications shall be considered adopted unless at least ten per cent. of the total membership shall vote in the negative.

Adjournment.

BOARD MEETING HELD JANUARY 14, 1909, HOTEL HOLLENDEN, CLEVELAND, OHIO.

Present: Richard L. Humphrey, President; George C. Wright, Secretary; H. C. Turner, Treasurer; and Merrill Watson, M. S. Daniels and A. T. Bradley, members of the Executive Board.

On motion Mr. W. P. Anderson was elected to the Chairmanship of the Sectional Committee on Specifications for Cement Products.

The Auditing Committee consisting of Mr. Merrill Watson and Mr. M. S. Daniels reported the annual statement of the Treasurer to be correct and the cash balance applying to the year 1908 to be $1,636.31.

REGISTER OF ATTENDANCE, FIFTH CONVENTION.

Richard L. Humphrey, Philadelphia, Pa.
Merrill Watson, New York, N. Y.
M. S. Daniels, Suffern, N. Y.
E. S. Larned, Boston, Mass.
George C. Walters, Atlanta, Ga.
George C. Wright, Rochester, N. Y.
H. C. Turner, New York, N. Y.
Leonard C. Wason, Boston, Mass.
William H. Ham, Boston, Mass.
Alfred E. Lindau, St. Louis, Mo.
Sanford E. Thompson, Newton Highlands, Mass.
L. V. Thayer, Minneapolis, Minn.
C. W. Boynton, Chicago, Ill.
W. P. Anderson, Cincinnati, Ohio.
Spencer B. Newberry, Sandusky, Ohio.
Abbey-Dodge-Brooks Concrete Company, Newark, N. J.
    Raymond E. Brooks.
Aberthaw Construction Company, Boston, Mass.
    Leonard C. Wason.
Adolph Adams, Kendallville, Ind.
H. L. Adkins, Jonesboro, Arkansas.
B. F. Affleck, Chicago, Ill.
Carl Ahlfeld, Bayonne, N. J.
Alge Brothers, Findlay, Ohio.
    Joseph Alge, Jr.
Alma Cement Company, Wellston, Ohio.
    D. S. Hoover.
American Cement Company, Philadelphia, Pa.
    Robert W. Lesley.
American Clay Machinery Company, Willoughby, Ohio.
    L. W. Penfield.

American Hydraulic Stone Company, Denver, Col.
Harmon H. Rice.
American Steel and Wire Company, Chicago, Ill.
H. S. Doyle.
Anchor Concrete Stone Company, Rock Rapids, Iowa.
Charles W. Bradley.
Armstrong Concrete Specialty Company, Inc., Boston, Mass.
A. B. Cochran.
Ashland Steel Range and Manufacturing Company, Ashland, O.
U. S. Shelly.
Atlas Portland Cement Company, New York, N. Y.
P. Austin Tomes.
Frank E. Atwater, Cleveland, Ohio.
Louis Auer & Son, Milwaukee, Wis.
Joseph Fehrer, Jr.
W. W. Ballantine, Cleveland, Ohio.
Walter F. Ballinger, Philadelphia, Pa.
F. M. Ballou Company, Providence, R. I.
F. B. Follett.
R. M. Balyeat, Van West, Ohio.
H. L. Barker, Flatbush, N. Y.
Henry A. Barkhausen, Green Bay, Wisconsin.
F. S. Barnum, Cleveland, Ohio.
F. Battjes, Grand Rapids, Mich.
Battjes Fuel and Building Material Company, Grand Rapids, Mich.
N. H. Battjes.
Bayliss Concrete Stone and Brick Company, Bessemer, Mich.
Jerome Z. Bayliss.
A. L. Bender, Topeka, Ind.
Newton D. Benson, Providence, R. I.
Berger Manufacturing Company, Canton, Ohio.
W. L. Caldwell.
Besser Manufacturing Company, Alpena, Mich.
J. H. Besser.
F. R. Bicklehaupt, Cleveland, Ohio.
Alexander C. Birnie, Ludlow, Mass.
Roy Black Engineering Company, Cleveland, Ohio.
Roy Black.

Blaw Collapsible Steel Centering Company, Pittsburg, Pa.
Jacob B. Blaw.
Benjamin Blethyn, Washington, D. C.
T. Hugh Boorman, New York, N. Y.
M. Bovee and Son, Northville, Mich.
Vernon D. Bower, New Trenton, Ind.
Edward D. Boyer, Catasauqua, Pa.
James Boyle, Freeland, Pa.
H. T. Boylen, Buchanan, W. Va.
Addison Brannin, Aberdeen, Miss.
Brown Hoisting Machinery Company, Cleveland, Ohio.
F. B. Burness, Kansas City, Mo.
Buser Concrete Construction Company, Mount Morris, Ill.
N. E. Buser, R. E. Buser.
Butler Wood Fiber Plaster Company, Butler, Pa.
S. C. Kelly.
A. W. Cadogan, Osceola, Pa.
Cadwell Silex Stone Company, West Windsor, Canada.
C. W. Cadwell.
Carlon Construction Company, Oskaloosa, Ia.
George H. Carlon.
Carey Construction Company, Cleveland, Ohio.
J. D. Carey.
Castalia Portland Cement Company, Sandusky, Ohio.
Charles L. Johnson.
Cement, New York, N. Y.
R. B. Seers.
Cement Age, Philadelphia, Pa.
E. A. Trego.
Cement and Engineering News, Chicago, Ill.
William Seafert.
Cement Era, Chicago, Ill.
E. S. Hanson.
Cement World, Chicago, Ill.
C. R. W. Edgecomb.
Central Construction Company, Wooster, Ohio.
I. A. Andrew.
Century Cement Machine Company, Rochester, N. Y.
A. T. Bradley.

Chain Belt Company, Milwaukee, Wis.
W. Rosebery.
Dana G. Chandler, Sylvania, Ohio.
William C. Charlton, Pittsburg, Pa.
Chicago Portland Cement Company, Chicago, Ill.
J. U. C. McDaniel.
J. H. Chubb, Chicago, Ill.
Cleveland and Pittsburg Coal Company, Cleveland, Ohio.
P. P. Quayle.
Cleveland Concrete Building Block Company, Cleveland, Ohio.
R. W. Russell.
Cleveland Furnace Company, Cleveland, Ohio.
D. T. Croxton.
Clover Leaf Machine Company, South Bend, Ind.
W. O. Williams.
J. H. Cochrane, Washington, D. C.
D. M. Collier, Albany, N. Y.
L. L. Compton, Wilmington, Ohio.
Concrete, Detroit, Mich.
Walter C. Boynton.
The Concrete Age, Atlanta, Ga.
George C. Walters.
Concrete Engineering, Cleveland, Ohio.
A. E. Warner.
Concrete Products Company, New York, N. Y.
Ross F. Tucker.
Concrete Stone and Sand Company, Youngstown, Ohio.
A. A. Pauly.
Concrete Stone Company, Providence, R. I.
E. D. Anthony.
C. H. Connell, Youngstown, Ohio.
A. B. Cook, Petersburg, Va.
Corrugated Bar Company, St. Louis, Mo.
John E. Conzelman.
John H. Cramond, Manistee, Mich.
A. J. Cromar, Brantford, Canada.
Crossett and Lloyd Concrete Company, Binghamton, N. Y.
Frank Crossett.

Crozier, Alfred O., Wilmington, Del.
D. and A. Post Mold Company, Three Rivers, Mich.
G. H. Dougherty.
B. H. Davis, Hoboken, N. J.
Harold M. Davy, Ottawa, Canada.
Wilbur C. Deeds, Cuyahoga Falls, Ohio.
Charles W. DeArmon, Piqua, Ohio.
George W. De Smet, Chicago, Ill.
Detroit Fireproofing Tile Company, Detroit, Mich.
A. C. Raymond.
Devine Concrete Company, Uhricksville, Ohio.
W. B. Devine.
Dietrichs Clamp Company, Little Ferry, N. J.
Charles Dietrichs.
J. A. Douglass, Alliance, Ohio.
Wesley E. Dyer, Muskegon, Mich.
Eagle Art Stone Company, Cleveland, Ohio.
Edward J. Marquard.
Eastern Concrete Machinery Supply Company, Akron, N. Y.
Eastern Concrete Construction Company, Boston, Mass.
William M. Bailey.
George Taylor.
Christian Eckhard, St. Louis, Mo.
Edison Portland Cement Company, Stewartsville, N. J.
M. S. Mallory.
Joseph F. Eilbacher, Elizabeth, N. J.
Arthur S. Eldridge, New York, N. Y.
Elyria Lumber and Coal Company, Elyria, Ohio.
H. B. Hecock.
Emerson and Norris Company, Boston, Mass.
Engineering Record, New York, N. Y.
F. S. Henry.
Davis Ewing Concrete Company, Bloomington, Ill.
Davis Ewing.
Ewing Concrete Machinery Company, Akron, Ohio.
L. D. Ewing.
Farquharson Realty Company, Flatbush, N. Y.
J. W. Farquharson.

Edward R. Felix, Passaic, N. J.
Frank F. Flickinger, Massillon, Ohio.
William S. Fogle, Broadway, Ohio.
J. B. Foote Foundry Company, Fredericktown, Ohio.
Fort Wayne Cement Stone Company, Fort Wayne, Ind.
J. A. Fowler, Waterville, Ohio.
Samuel H. French and Co., Philadelphia, Pa.
C. Weber Jones.
G. F. Frink and Son, Elk Rapids, Mich.
G. F. Frink.
Garden City Sand Company, Chicago, Ill.
S. W. Curtiss.
Gary Iron and Steel Company, Cleveland, Ohio.
Mr. Siddall.
C. W. Gaylord, Chicago, Ill.
General Fireproofing Company, Youngstown, Ohio.
E. N. Hunting, D. S. Donahue.
William J. Genther, Despatch, N. Y.
R. A. Gibson, Hot Springs, Ark.
George H. Gill, Surprise, Neb.
J. Robert Gill, Chicago, Ill.
Peter Gillespie, Toronto, Canada.
James R. Gloyd, Cleveland, Ohio.
M. K. Gochnauer, Appleton, Wis.
E. P. Goodrich, New York, N. Y.
Good Roads Magazine, New York.
H. L. Powell.
Frank A. Grady, Cuba, N. Y.
B. A. Graves Company, Lexington, Ky.
George T. Graves.
W. S. Griswold, Elyria, Ohio.
Albert Acton Hall, Piqua, Ohio.
W. L. Hall, Dyersburg, Tenn.
L. Hallowell, Findley, Ohio.
Hansen and Nelson, Manistee, Mich.
Christian Hansen.
C. B. Hastings, Brookville, Pa.
Leonard C. Hatch, Piqua, Ohio.

Alfred G. Hathaway, Cleveland, Ohio.
W. K. Hatt, Lafayette, Ind.
Robert F. Havlik, South Bend, Ind.
Hayden Automatic Block Machine Company, Columbus, Ohio.
W. B. Simpler.
William N. Hazen, New York, N. Y.
Veeder Heasley, Youngstown, Ohio.
Charles A. Hoff, Lykens, Pa.
S. W. Hoffman, Zanesville, Ohio.
W. C. Holmes, Portland, Ind.
Henry N. Hooper, Cincinnati, Ohio.
James G. Hopper, Ridgewood, N. J.
A. C. Horn Company, New York, N. Y.
A. C. Horn.
Hot Springs Concrete Company, Hot Springs, Ark.
C. E. Marks.
F. W. Howard, Hartford, Conn.
Charles S. Howe, Cleveland, Ohio.
B. A. Howes, New York, N. Y.
Hutchens and Friske, Milwaukee, Wis.
O. B. Hutchens.
Ideal Concrete Machinery Company, South Bend, Ind.
Mentor Wetzstein.
Illinois Gravel Company, Princeton, Ill.
C. F. Scott.
Fred K. Irvine, Chicago, Ill.
William R. Isley, Waverly, N. Y.
F. M. Jackson Company, Akron, Ohio.
E. E. Jackson, Fremont, Ohio.
Jansen and Zoeller, Pekin, Ill.
D. H. Jansen.
Jeannette Concrete Construction Company, Jeannette, Pa.
S. F. Boyer.
Jeffer and Christopher, Ridgewood, N. J.
Joseph H. Christopher.
J. Y. Jewett, Denver, Col.
Willard N. Jones, Corry, Pa.
J. E. Jordan, Cuba, N. Y.

Kent Machine Company, Kent, Ohio.
F. A. Kershaw.
Kerlin Automatic Post Machine Company, Delphi, Ind.
E. W. Bowen.
A. J. Ketchin and Son, Tarriffville, Conn.
W. M. Ketchin.
William M. Kinney, Pittsburg, Pa.
C. F. Kleiderer and Son, Henderson, Ky.
C. F. Kleiderer.
C. R. Knapp and Co., Philadelphia, Pa.
C. R. Knapp.
Knickerbocker Chemical Company, New York, N. Y.
T. Hugh Boorman.
Knickerbocker Company, Jackson, Mich.
W. B. Knickerbocker.
Knightstown Concrete Company, Knightstown, Ind.
H. Watts.
Koehring Machine Company, Milwaukee, Wis.
Phil. A. Koehring, William J. Koehring.
Adam B. Kraft, York, Pa.
Lake Erie Builders' Supply Company, Cleveland, Ohio.
W. C. Runyan, Jr.
Edward J. Landor, Canton, Ohio.
Lawrence Cement Company of Pennsylvania, Plainfield, N. J.
W. S. Gifford.
J. B. Leach, Carthage, N. Y.
David B. Ledlie, Saratoga Springs, N. Y.
John A. Leffler, Hazleton, Pa.
Lehigh Portland Cement Company, Allentown, Pa.
P. A. Jaundernal.
H. A. Lensing, Evansville, Ind.
Frank Lewis, Harpursville, N. Y.
Fred T. Ley and Co., Inc., Springfield, Mass.
M. W. Denman.
T. Linday, Erie, Pa.
B. F. Lippold, Chicago, Ill.
Samuel Liston, Mansfield, Ohio.
Livonia Cement and Block Factory, Livonia, N. Y.
John Nickerson.

Walter O. Lloyd, Binghamton, N. Y.
P. F. Longacher and Co., Elkhart, Ind.
P. T. Longacher.
Samuel Lutton, Point Pleasant, W. Va.
George V. Lynn, Pen Argyl, Pa.
Macafee Concrete Company, Athens, Pa.
S. B. Macafee.
J. C. Manning.
E. P. Mantz, Frederick, Md.
Arthur J. Maynard, State Farm, Mass.
F. K. Mayne, Blue Springs, Neb.
Ernest McCullough, Chicago, Ill.
George B. McMillan, Cleveland, Ohio.
Samuel MacMullin, Riverton, N. J.
John R. McVey, Cuba, N. Y.
Meriden Concrete Company, Meriden, Conn.
Edward L. Montgomery.
Merritt and Co., Camden, N. J.
G. D. Wilson.
Michall and Hart, Mahanoy City, Pa.
O. J. Michall.
Charles R. Miller Company, Inc., Memphis, Tenn.
Charles R. Miller.
Charles M. Mills, Philadelphia, Pa.
John R. Minnick, Longport, Atlantic City, N. J.
Miracle Pressed Stone Company, Minneapolis, Minn.
O. U. Miracle.
R. O. Miracle, Helena, Mont.
William Morton, Cleveland, Ohio.
Albert Moyer, New York, N. Y.
Multiplex Concrete Machinery Company, Toledo, Ohio.
W. R. Dawson.
Municipal Engineering and Contracting Company, Chicago, Ill.
T. M. Meek.
Samuel Munnel, Canonsburg, Pa.
National Roofing Company, Tonawanda, N. Y.
F. A. Fuller.
National Wire Cloth Company, Sandusky, Ohio.
George T. Schade.

B. F. Neff and Son, Bryan, Ohio.
B. F. Neff.
New England Cement Stone Company, Norwood, Mass.
George E. Sanborn.
New Jersey Cement Construction Company, Newark, N. J.
Clifford F. MacEvoy.
Nice-Rasor Company, Barberton, Ohio.
C. O. Rasor.
J. Frank Norris, Rochester, N. Y.
Northwestern Expanded Metal Company, Chicago, Ill.
A. J. Maul.
Norwalk Vault Company, Norwalk, Ohio.
C. L. French.
Ogden and Cadmus, Bloomfield, N. J.
E. L. R. Cadmus.
Oneida Community, Limited, Oneida, N. Y.
Theodore H. Skinner.
Ornamental Stone Company, Lansing, Mich.
L. C. Briggs.
O. B. Parsons, Camp Perry, Ohio.
Joseph Patterson, St. Marys, Canada.
Payne Cement Company, Mansfield, Ohio.
J. E. Payne.
Peerless Brick Machine Company, Minneapolis, Minn.
L. V. Thayer.
Pennsylvania Cement Company, New York, N. Y.
William Beck.
Emile G. Perrot, Philadelphia, Pa.
Don J. Perry, Quebec, Canada.
Thomas Phillips Company, Akron, Ohio.
F. S. Phipps, St. Joseph, Mo.
Plainfield Cement Stone Company, Plainfield, N. J.
R. G. Bush.
M. C. Platt, Pittsburg, Pa.
Harry Franklin Porter, Philadelphia, Pa.
L. E. Porter, York, Neb.
W. Porter, Mackinaw, Ill.
Charles M. Potter, Naugatuck, Conn.

George C. Prince, Camden, N. J.
George B. Pulfer, South Bend, Ind.
Herman E. Rackle, Cleveland, Ohio.
B. H. Rader, Pittsburg, Pa.
Radtke-Walter Company, Monroe, Mich.
    August Radtke.
Lloyd E. Ragan, Schenectady, N. Y.
A. Edward Ranney, Cleveland, Ohio.
Ray Manufacturing Company, Philadelphia, Pa.
    S. E. Gilbert.
John S. Reiff, Lykens, Pa.
Harvey W. Remington, New York, N. Y.
Ricketson Mineral Paint Works, Milwaukee, Wis.
    Edward Bogk.
Jay S. Rightmyer, Auburn, N. Y.
E. A. Roberts, Cleveland, Ohio.
Rock Products, Chicago, Ill.
    E. H. Defebaugh.
Henry F. Romaine, Jr., Columbus, Ohio.
Oliver Rosenberger, Lansdale, Pa.
Ernest S. Ross, St. Joseph, Mo.
Runyan Concrete Machinery Company, Canal Dover, Ohio.
    H. W. Streb.
Saal and Brooking, Pekin, Ill.
    Adam Saal.
Sandusky Portland Cement Company, Sandusky, Ohio.
    Spencer B. Newberry.
W. W. Schouler, Newark, N. J.
Herman F. Schultz, Napoleon, Ohio.
John P. Schuyler, Medina, N. Y.
Searles, Hirsch and Gavan, Cleveland, Ohio.
    A. Hirsch.
Simpson Brothers Corporation, Boston, Mass.
    J. B. Simpson, H. B. Andrews.
Simpson Cement Mold Company, Columbus, Ohio.
    H. G. Simpson.
T. L. Smith Company, Milwaukee, Wis.
    I. S. McDonald.

George Smith, Jr., Kearney, N. J.
J. Augustine Smith, South Bend, Ind.
Soper Company, Detroit, Mich.
Ellis Soper.
William N. Sortor, Bloomfield, N. J.
Southern Tile and Stone Company, Atlanta, Ga.
T. D. Meador, Jr.
Henry S. Spackman Engineering Company, Philadelphia, Pa.
H. S. Spackman.
A. F. Spangler and Co., East Orange, N. J.
A. F. Spangler.
William Spangler, Newark, N. J.
E. N. and R. E. Spaulding, Suffield, Conn.
Ralph E. Spaulding.
Alvah F. Stahl, Ridgewood, N. J.
Sterling Engineering and Construction Company, Milwaukee, Wis.
Gustav E. Kahn.
Steubenville Stone Company, Steubenville, Ohio.
Frank Stecker.
George H. Stewart, East Salamanca, N. Y.
Kennedy Stinson, Montreal, Canada.
Stocker Gravel and Artificial Stone Company, Highland, Ill.
Fred. Stocker.
George W. Stone, Worcester, Mass.
Stowe-Fuller Company, Cleveland, Ohio.
Charles A. Stowers, Akron, Ohio.
Cornelius J. Sullivan, Syracuse, N. Y.
Superior Cement Roofing Company, Bryan, Ohio.
H. M. Kelly.
Superior Portland Cement Company, Cincinnati, Ohio.
Charles Schmutz.
H. A. Suter, St. Joseph, Mo.
Svenson-Shuman Machine Company, Pittsburg, Pa.
John Svenson.
Tarbox and McCall, Findlay, Ohio.
Harry Tarbox.
W. Purves Taylor, Philadelphia, Pa.

Alfred W. Thorn, Buffalo, N. Y.
J. H. Thornhill, Winchester, Ind.
Edward Tingle, Eaton, Ohio.
Tinker Concrete and National Vault Company, Cleveland, Ohio.
S. A. Drake.
Turner Construction Company, New York, N. Y.
J. P. H. Perry.
John J. Turner, Amsterdam, N. Y.
John P. Turner, Amsterdam, N. Y.
United Cement Machinery Manufacturing Company, Plain City, Ohio.
M. C. Haggerty.
Universal Portland Cement Company, Chicago, Ill.
Edward M. Hagar.
Day P. Vining, Jackson, Mich.
Virginia Concrete and Engineering Company, Rocky Mount, Va.
E. V. N. Heermance.
Vulcanite Portland Cement Company, New York, N. Y.
Wadsworth, Howland and Co., Inc., Boston, Mass.
F. A. Gunnison.
H. J. Wahl and Co., Lykens, Pa.
H. J. Wahl.
Henry P. Warner, Syracuse, N. Y.
Charles D. Watson, Syracuse, N. Y.
Watterson and Schneider, Cleveland, Ohio.
William Watterson.
Raymond B. Way, Brooklyn, Ohio.
Charles J. Welch, Victoria, Texas.
West Park Block Company, West Park, Ohio.
M. M. Lutz.
Wettlaufer Brothers, Buffalo, N. Y.
George Wettlaufer.
White and Shupe, Cleveland, Ohio.
M. White.
Whitehall Portland Cement Company, Philadelphia, Pa.
Howard B. Green.
Frank C. Wight, New York, N. Y.
H. M. Wilson, Washington, D. C.

Percy H. Wilson, Philadelphia, Pa.
George W. Winship, Saratoga Springs, N. Y.
Wiselogel and Co., Muskegon, Mich.
W. F. Wiselogel.
Frederick E. Wyatt, Rochester, N. Y.
Young Concrete and Construction Company, Waterbury, Conn.
E. J. Young.
H. M. Young and Son, Eaton, Ohio.
Zeiser Brothers, Berwick, Pa.
John R. Zeiser.
Albert J. Zemmer, Port Huron, Mich.
Henry Zolfer, Mendota, Ill.

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LIST OF EXHIBITORS AND ATTENDANTS, FIFTH EXHIBITION.

Akron Gravel and Sand Company, Akron, O.
George Carmichael, J. H. Meyers, W. E. Wright, J. E. Peterson, Austin Graff, C. Mulcahey.

Alma Cement Company, Wellston, O.
D. S. Hoover, R. S. Cape, S. G. Powell, A. F. Clark.

American Cement Company, Philadelphia, Pa.
J. A. Camm, J. J. Shippard, J. Walker, J. J. Dempsey, H. Oliver, C. M. Camm, R. W. Lesley.

American Cement Roofing Company, Columbus, Ohio.
J. E. Hicks, Elias Risewick.

American Hydraulic Stone Company, Denver, Col.
Harman H. Rice, J. Robert Gill, Mr. Harrig, Mr. Barron, Mr. Wall, H. A. Wilcox.

American Steel and Wire Company, Chicago, Ill.
H. S. Doyle, L. Bloomfield, R. H. Pratt, H. T. Pratt, E. Angle, C. Mitchell.

Anchor Concrete Stone Company, Rock Rapids, Iowa.
S. Black, Charles W. Bradley, J. E. Coffin, S. D. Rinike.

Ashland Steel Range and Manufacturing Company, Ashland, O.
U. S. Shelly, A. J. Bentz, B. A. Tinkey, Ed. Brooks, Sam. Botdorf.

Atlas Portland Cement Company, New York, N. Y.
C. A. Kimball, P. A. Tomes, R. L. Beck, James Purches, C. S. Miller, John Klein, Harry Woods, John Cooper, Charles Bunham, Ed. D. Boyer, E. Lunday, L. Evans.

Association of American Portland Cement Manufacturers, Philadelphia, Pa.
Percy H. Wilson, C. W. Gaylord.

Louis Auer and Son, Milwaukee, Wis.
Joseph Fehier, Jr., A. Reichert.

Ballou Manufacturing Company, Belding, Mich.
M. Ballou, B. B. Swartwout.

Barrett Manufacturing Company, New York, N. Y.
D. J. Perry, C. J. Bileger, O. H. Judson.

Besser Manufacturing Company, Alpena, Mich.
J. H. Besser, J. Charge, B. Coll, E. Welch, A. Ralph, H. Baldwin, C. Welch, R. Eggie, A. Cooper, J. Miller, N. Hanson, W. R. McDheo.

Billings-Chapin Company, Cleveland, O.
R. W. Western, D. W. Roberts, N. D. Chapin, Miss Geppes, Miss Metzdorf.

Blaw Collapsible Steel Centering Company, Pittsburg, Pa.
Jacob Blaw, H. B. Loxterman, M. Lehman, A. C. Lehman, J. J. Ryan, Thomas S. Ryan, Paul W. Keim, Mrs. Jacob Blaw.

M. Bovee and Son, Northville, Mich.
W. E. Richardson.

Brown Hoisting Machinery Company, Cleveland, O.
A. R. Leeds, J. F. Laucks, George T. Sinks, W. H. Huelsman, A. Hendrickson, F. A. Peck.

Buckeye Concrete Company, Creston, Ohio.
J. P. Heckman, Charles Hay, Davis Stusman.

F. B. Burness, Kansas City, Mo.
A. J. McGarvey, J. Tavenner.

Cement Age, New York, N. Y.
A. E. Trego, F. Lincoln, A. Ferry.

Cement Era, Chicago, Ill.
E. S. Hanson, H. W. Baumgartner, H. Baumgartner, R. E. Montgomery.

Cement Machinery Company, Denver, Colo.
S. H. Wiltse, J. C. Lautenslager, William C. Hartigan, A. W. Lawrence, S. C. Smith, George H. Perrine, J. E. Wilbur.

Cement Tile Machinery Company, Waterloo, Iowa.
W. H. Stewart, W. S. Northrop, F. W. Kennedy, Godfrey Gross, C. B. Farmhid, M. P. Northcott, F. H. Stewart.

Cement World, Chicago, Ill.
C. R. W. Edgecomb, J. A. Smith, Miss Jones, Miss Gray, Miss White.

Century Cement Machine Company, Rochester, N. Y.
A. T. Bradley, C. B. Ross, D. M. Osborne, H. Sharpe, L. H. Finley, J. N. Rauber.

Chain Belt Company, Milwaukee, Wis.
W. Rosebery, C. Rosebery, D. Frasier, M. L. Sargent.
Chase Foundry and Machine Company, Columbus, O.
Edward Kaemerer, T. W. Chase, W. C. Stocklin.
Clover Leaf Machine Company, South Bend, Ind.
W. O. Williams, C. H. Louis, M. Sheffield.
Coltrin-Boos Company.
C. J. Boos, M. F. Morris.
Concrete Age, Atlanta, Ga.
George C. Walters, J. D. Walters.
Concrete, Detroit, Mich.
W. C. Boynton, R. Marshall, C. B. Wolfram, M. W. Michelbery, John Waldron.
Concrete Stone and Sand Company, Youngstown, O.
A. A. Pauly, W. Fleming, Frank Kyle, Thomas McKelvy, E. L. Williams, Herman Rathfoos, E. S. Walter, C. H. Connell, R. Garlick.
Corrugated Bar Company, St. Louis, Mo.
C. Ferguson, John E. Conzelman, Mrs. J. E. Conzelman.
D. and A. Post Mold Company, Three Rivers, Mich.
G. W. Dougherty, J. B. Roberts, K. L. Shoemaker.
De Armond-McKinney Manufacturing Company, Piqua, O.
J. S. McKinney, C. W. De Armond.
Dietrichs Clamp Company, Little Ferry, O.
C. Dietrichs, J. C. Kichlan, F. W. Wright.
Edison Portland Cement Company, Stewartsville, N. J.
E. Meyer, R. H. Backman, F. B. Marsh, J. H. McCreichen, James Bernard, W. S. Mallory, J. D. Mucklin, J. H. Hoover, E. R. Miller, J. H. Wakeman, S. Churchill, Harry Hunter, Charles V. Reed.
Eureka Machine Company, Lansing, Mich.
O. S. Case, W. O. Johnson, Fred Fisher, Frank Ryan, Arthur Bradley, Miss Halliday.
J. B. Foote Foundry Company, Fredericktown, O.
J. B. Foote, C. R. Hany, S. H. Breittinger, Jay Foote.
Garden City Sand Company, Chicago, Ill.
L. W. Curtiss, C. H. Rose, S. G. Webb.
F. G. Gaunt Manufacturing Company, Fort Wayne, Ind.
W. D. Miller, F. G. Gaunt.

General Fireproofing Company, Youngstown, O.
E. N. Hunting, F. K. Rhines, I. W. Murray, P. R. Clark, B. W. Ransom.

Good Roads Magazine, New York City.
E. Powers, H. Powell, J. Brown.

Hall-Holmes Manufacturing Company, Jackson, Mich.
S. P. Holmes, C. W. Hall, E. J. Curtis.

Hayden Automatic Block Machine Company, Columbus, O.
W. B. Simpler, W. H. Remington, George Friel, H. Mooren, E. Van Lynn, Henry Metzer, R. Black, L. G. Foster, L. C. Foster.

Ideal Concrete Machinery Company, South Bend, Ind.
M. Wetzstein, J. Augustine Smith, G. B. Pulfer, H. B. Gregory, F. W. Leach, O. F. Wampler, Carl Greiner, George Augrault, Robert F. Havlik, George B. Hopkins, N. E. Kennedy, E. B. Kelly, Mike Butzolik, Paul Butzolik.

Indiana Concrete Form Company, Indianapolis, Ind.
J. H. Wiest, I. D. Wiest, Irwin Tenant, C. W. Howland, J. C. Hutchison, A. L. Duncan, John W. Brady.

Insley Manufacturing Company, Indianapolis, Ind.
C. Dunning, G. Chandler, W. Insley.

F. M. Jackson Company, Akron, O.
F. M. Jackson, H. S. Avery, N. C. Hoag, Charles Reese, W. A. Carey.

Kent Machine Company, Kent, O.
F. A. Kershaw, F. H. Merrill, E. M. Barker, A. L. Post.

Kerlin Automatic Post Machine Company, Delphi, Ind.
W. F. Kerlin, E. W. Bowen, J. H. Mount, C. M. Williams, D. Y. Robertson, S. B. Davidson.

Knickerbocker Company, Jackson, Mich.
M. B. Knickerbocker, D. C. Schaffer, C. B. Western.

Knickerbocker Chemical Company, New York, N. Y.
T. Hugh Boorman, J. J. McWall, Al. Horn.

Koehring Machine Company, Milwaukee, Wis.
W. J. Koehring, W. Ord, H. Trevor, W. Williams, R. Moss, F. Johnson.

The Lawrence Cement Company, Philadelphia, Pa.
W. S. Gifford, F. Case, F. A. Sarstedt, M. Drake, J. Tinker, N. Callahan, D. Pfahl.

La Grange Specialty Company, La Grange, Ind.
N. E. Snyder, H. A. Smith, H. Reeser, J. E. McIntyre, J. D. Stacy.

Lehigh Portland Cement Company, Allentown, Pa.
P. A. Jaundernal, F. E. Paulson, B. L. Suritt, Tom Scott, Henry Angel, A. N. Gawn, George J. Klamm, F. H. Holland, W. E. Viets, J. H. Black, K. C. Bolton.

Marblecrete Products Company, Akron, N. Y.
R. Thomas, R. N. Cunningham, H. S. Town, C. F. Town, W. V. Johnson, Benjamin Blythen, T. Meadors, J. N. Macpherson.

Miles Manufacturing Company, Inc., Jackson, Mich.
D. P. Vining, W. J. Corbett, A. J. Weatherwax, Jr., C. E. Vining, Milton Lutz, Harry Lutz, C. L. Vining, Warren Snyder.

Miracle Pressed Stone Company, Minneapolis, Minn.
O. U. Miracle, R. C. Miracle, C. D. Russell, E. Haight, G. Davie, F. Conklin, F. Scott, G. Bidwell, S. Foster, R. Mack, H. Kirtley, G. Price, Miss Johnson.

Multiplex Concrete Machinery Company, Toledo, O.
W. R. Dawson, R. E. Feets, W. H. Peters, L. H. Keller, A. Feilback.

M. A. Munn Company, Cleveland, Ohio.
M. A. Munn, R. E. Bayer, C. W. Stevens.

Municipal Engineering and Contracting Company, Chicago, Ill.
T. M. Meals, C. E. Bathrick, Herman Westling.

National Roofing Company, Tonawanda, N. Y.
F. A. Fuller, W. W. Fluker.

National Wire Cloth Company, Sandusky, Ohio.
G. Schade, S. E. Emerson, R. Ramsdal, W. Brainard, W. L. Feninger, W. D. Ferguson, C. K. Ferguson, Phil Gaghen.

Northwestern Expanded Metal Company, Chicago, Ill.
A. J. Maul.

Norwalk Vault Company, Norwalk, O.
Don Kidwell, Ed. Green, F. H. Evans, H. Davies.

Ohio Ceramic Engineering Company, Cleveland, Ohio.
Lloyd Brown, A. W. French, F. H. Robinson, H. A. Reader, Arthur Dowd, Mr. Dailey.

Oneida Community Company, Limited, Oneida, N. Y.
Theo. H. Skinner, E. D. Pitt, M. Kinsley, L. McFarland.

Pattison Supply Company, Cleveland, O.
W. M. Pattison, M. Jones, C. E. McCombs, E. E. Day, C. Frank, E. Haserodt, W. H. Smith, W. F. Geiger.

Peerless Brick Machine Company, Minneapolis, Minn.
L. V. Thayer, J. J. Palmer, Carl Jackson, F. E. Atwater, C. E. Patterson, L. N. Thomson.

Pennsylvania Cement Company, New York, N. Y.
William Beck, William Ball, William Kind, F. Walker, C. F. Scott, L. H. Scott, A. J. Fisher, George Vessels.

Raber-Lang Manufacturing Company.
R. L. Raber, J. E. Lang, J. Watts.

George Rackle and Sons Company, Cleveland, O.
H. E. Rackle, E. E. Rackle, F. R. Bicklehaupt, George Rackle, Charles Tennent.

Ransome Concrete Machinery Company, Dunellen, N. J.
A. W. Ransome, O. T. Wedmeyer, J. P. Faber.

Runyan Concrete Machinery Company, Canal Dover, O.
H. W. Streb, J. Steel, Henry Steel, A. Humbed, S. L. Holmes, H. E. Gresham, H. Brockhauser, H. Grathenrath.

Rutherford Cement Construction Company, Rutherford, N. J.
J. Jaeger, J. Malatki, T. Calaro.

Sandusky Portland Cement Company, Sandusky, O.
A. St. John Newberry, Frederick Arnold, W. W. Kingsley, R. W. Russell, H. C. Stienson, W. C. Brickman, K. R. Fish, P. B. Berry.

Sanford Concrete Machinery Company, Toledo, Ohio.
J. J. Cox, A. M. Abbott, R. W. Ostermiller, Ed. Krozier, Dave Haskinson, C. W. Conklin, E. J. Long, Fred Gribbell, J. B. Gribbell, E. Night.

Simpson Cement Mold Company, Columbus, O.
H. G. Simpson, E. C. Bending, L. C. Ross, A. W. Simpson, G. W. Simpson.

The T. L. Smith Company, Milwaukee, Wis.
I. S. McDonald, R. C. McCombs, F. May, A. T. Dexter, J. M. Finney, R. A. Winchester, Henry C. Froor, Myron Seibert.

R. Z. Snell Manufacturing Company, South Bend, Ind.
William Lechlitner, O. B. Johnson, A. Huntsberger, F. Kinley, C. Sixby.

Somers Block Machine Company, Urbana, Ill.
F. A. Somers, E. H. Somers, D. C. Lean, J. H. Hoke, John Gray.

Standard Construction Company.
E. Van Lehn, Mrs. E. Van Lehn, C. P. Ewing, C. D. Edwards.

Superior Portland Cement Company, Charleston, W. Va.
C. F. Harwood, Charles Schmitz.

Svenson-Shuman Company, Pittsburg, Pa.
J. S. Svenson, E. C. Riddle.

Technical Publishing Company, Cleveland, O.
F. D. Leslie, Allen Brett, H. Farrand, A. E. Warner, M. A. Lee.

Tinker Concrete Company, Cleveland, O.
S. A. Drake, A. Hunt, L. D. Munson.

United Cement Machinery Manufacturing Company, Plain City, O.
M. Sanderson, M. C. Haggerty, S. M. Coe, G. Jaeger, A. E. Davis, S. N. Linn, W. O. Brush, George Philipo, H. L. Green, R. S. Black.

Universal Portland Cement Company, Chicago, Ill.
Edward M. Hager, J. P. Beck, W. S. Wing, J. Hulback, T. Hughes, M. Koch, T. Fugua, M. Metcalf.

Vulcanite Portland Cement Company, New York City.
Albert Moyer, Floyd A. Walter, W. Moffet, C. Herche.

Wadsworth-Howland Company, New York, N. Y.
F. A. Gunnison, E. A. Foster, W. A. Fox, R. Mitchell, C. Miller, R. Beck.

Wettlaufer Brothers, Buffalo, N. Y.
G. Wettlaufer, W. Wettlaufer, C. Wettlaufer, E. Wettlaufer, T. E. Day.
Whitehall Portland Cement Company, Philadelphia, Pa.
H. B. Green, H. Rauch, James B. Weaver, Mrs. Weaver.
S. H. Wightman Company, Cleveland, O.
S. H. Wightman, Mrs. S. H. Wightman, H. C. Kelly, Sr., H. J. Kelly, Jr.
Zeiser Brothers, Berwick, Pa.
A. Zeiser, J. R. Zeiser, William Gilbert.

LIST OF MEMBERS.

Contributing members are distinguished thus (*).

ABBEY-DODGE-BROOKS CONCRETE COMPANY, THE. Raymond E. Brooks, Treasurer, 3 Passaic Street, Newark, N. J.

*ABERTHAW CONSTRUCTION COMPANY. Leonard C. Wason, President, 8 Beacon Street, Boston, Mass.

ACME CEMENT BLOCK COMPANY. Wellsburg, W. Va.

ADAMS, ADOLPH. Building Blocks, Kendallville, Ind.

ADAMS, JOHN H. Secretary and Treasurer, Beloit Concrete Stone Company, Beloit, Wis.

ADKINS, H. L. Concrete Contractor, 529 Huntington Avenue, Jonesboro, Arkansas.

AFFLECK, B. F. General Sales Agent, Universal Portland Cement Company, 1430 Commercial National Bank Building, Chicago, Ill.

AHLFELD, CARL. Manager, Perfection Concrete Stone Company, 35 West Twenty-fifth Street, Bayonne, N. J.

ALABAMA CONSOLIDATED COAL AND IRON COMPANY. Guy R. Johnson, Vice-President and General Manager, 825 First National Bank Building, Birmingham, Ala.

ALEXANDER, CHARLES A. Engineer and Contractor, Batavia, N. Y.

ALGE BROTHERS. Concrete Contractors, Joseph Alge, Jr., 811 West Main Street, Findlay, Ohio.

ALLEN, LUCIUS E. Director, Ontario Limestone and Clay Company, Limited, Post Office Box No. 22, Belleville, Ontario, Canada.

ALMA CEMENT COMPANY. D. S. Hoover, Sales Manager, Wellston, Ohio.

ALPHA PORTLAND CEMENT COMPANY. Easton, Pa.

ALTOONA CONSTRUCTION AND CONTRACTORS' SUPPLY COMPANY. Frank Brandt, President, Altoona, Pa.

Alton Roofing, Artificial Stone and Supply Company. Alton, Ill.

*American Cement Company, Robert W. Lesley, President, 604 Pennsylvania Building, Philadelphia, Pa.

American Clay Machinery Company, The. L. W. Penfield, Vice-President, Willoughby, Ohio.

American Concrete Company, The. N. S. Potter, Jr., President and General Manager, 515 South Second Street, Independence, Kansas.

American Hydraulic Stone Company. Harmon H. Rice, Secretary, 221 Railway Exchange Building, Denver, Col.

*American Steel and Wire Company. H. S. Doyle, Manager Concrete Reinforcement Department, 1340 Commercial National Bank Building, Chicago, Ill.

Anchor Concrete Stone Company. Charles W. Bradley, Manager, 312 Main Street, Rock Rapids, Iowa.

Angell, J. F. First Vice-President and Treasurer, Cement Machinery Manufacturing Company, 52 West Maple Street, Columbus, Ohio.

Angle, Samuel P. Angle Construction Company, Hagerstown, Md.

Argollo, Miguel de Teive e. Chief Engineer, San Francisco Railroad Company, Caixa, Postal 89, Bahia, Brazil

Armstrong Concrete Specialty Company, Incorporated, The. Ben Cochran, President, 189 Devonshire Street, Boston, Mass.

Art Concrete and Construction Company. Frederick H. Mattlage, Secretary and Treasurer, 417 Fresh Pond Road, Evergreen, Borough of Queens, N. Y.

Ash Grove Lime and Portland Cement Company. L. T. Sunderland, First Vice President, R. A. Long Building, Kansas City, Mo.

Ashland Steel Range and Manufacturing Company. U. S. Shelly, Treasurer and Manager, Ashland, O.

Atlanta Concrete Manufacturing and Construction Company. Atlanta, Ga.

*Atlas Portland Cement Company. J. Rogers Maxwell, President, 30 Broad Street, New York, N. Y.

Atwater, Frank E. General Manager, Tony Lanese and Company, 6210 Harvard Avenue, S. E., Cleveland, Ohio.

AUER AND SON, LOUIS. William Porth, Jr., Second Ward Bank Building, Milwaukee, Wis.

AUSTIN, LUCIEN A. Secretary-Treasurer, Penn Concrete Company, Olney, Philadelphia, Pa.

BABOCK, D. C. Springville, N. Y.

BABICZKY, JOSEPH. Civil Engineer, Landwehrstrasse 9, Halle, a. S., Germany.

BAILEY, H. L. Cement Inspector, City Hall, Chicago, Ill.

BAILEY AND COMPANY, W. W. Concrete Contractor, Chadwick, Illinois.

BALANTINE, W. W. The Addison, 1498 Addison Road, Cleveland, O.

BALL BROTHERS: Concrete Contractors, Twin Falls, Idaho.

BALLINGER, WALTER F. Ballinger & Perrot, Architects and Engineers, Boyertown Building, Philadelphia, Pa.

BALLOU COMPANY, F. M. Concrete Contractors, F. B. Follett, Manager, 1323 Broad Street, Providence, R. I.

BALLOU MANUFACTURING COMPANY. R. A. Reynolds, Belding, Mich.

BALLWEG, E. C. Concrete Contractor, 719 Comar Street, Emporia, Kansas.

BALYEAT, R. M. Balyeat Coal and Cement Company, Van West, O.

BARKER AND NIGHSWANDER. Jefferson Avenue and Water Street, Toledo, O.

BARKER, H. L. Farquharson Realty Company, 807 Beverly Road, Flatbush, N. Y.

BARKER, DR. W. S. 358 South Main Street, Dayton, O.

BARKHAUSEN, HENRY A. Green Bay, Wisconsin.

BARNUM, F. S. Architect, Superintendent of Buildings, Board of Education, Board of Education Building, Cleveland, Ohio.

BARR, J. L. H. Batavia, O.

BARTLETT, G. S. Vice-President, Western Portland Cement Company, Milwaukee, Wis.

BARTLETT LUMBER COMPANY, THE. J. L. Bartlett, Secretary and Treasurer, Greeley, Col.

BATTJES, F. Battjes Fuel and Building Material Company, Grand Rapids, Mich.

BATTJES FUEL AND BUILDING MATERIAL COMPANY. N. H. Battjes, Superintendent, 1001 South Division Street, Grand Rapids, Mich.

BAYLISS CONCRETE STONE AND BRICK COMPANY. Jerome Z. Bayliss, Manager, Bessemer, Mich.

BEAN, W. WORTH, JR. Civil Engineer, 217 Pipestone Street, Benton Harbor, Mich.

BEATTY, J. C. California Art Stone Supply Company, 510 Board of Trade, Toronto, Ontario, Canada.

BEDDELL, H. W. Bloomfield, Ontario, Canada.

BEIRER, W. AND H. 813 East Sixth Street, Alton, Ill.

BELL, WILLIAM. 509 Hill Avenue, Elgin, Ill.

BELLEFONTE LUMBER COMPANY. Bellefonte, Pa.

BELLEVUE STONE COMPANY. C. R. Callaghan, President, Bellevue, O.

BELLINGRODT, N. O. Concrete Engineer, 920 Empire Building, Atlanta, Ga.

BENDER, A. L. Concrete Contractor, Topeka, Ind.

BENNER, E. E. 217 South Seventeenth Street, Lincoln, Neb.

BENSON, NEWTON D. President, The Cement and Concrete Construction Company, 75 Westminster Street, Providence, R. I.

BERGER MANUFACTURING COMPANY. W. L. Caldwell, Manager, Fireproofing Department, Canton, Ohio.

BERTHELET CONCRETE STONE COMPANY. 7 Plankinton Building, Milwaukee, Wis.

BESCH AND BEEBE. Engineers and Contractors. Henry R. Beebe, 15 Mann Building, Utica, N. Y.

BESSER MANUFACTURING COMPANY, THE. J. H. Besser, Secretary, Alpena, Mich.

BEYER, IRA. Manufacturer of Cement Blocks, Mishicot, Wis.

BICKLEHAUPT, F. R. George Rackle and Sons Company, 4515 Superior Avenue, Cleveland, Ohio.

BINGHAM, L. L. Cement Products Company, Estherville, Iowa.

BIRNIE, ALEXANDER C. Engineer and Contractor. 7 Howard Street, Ludlow, Mass.

BLACKBURN, W. L. Hillsboro, Ill.

BLACK ENGINEERING COMPANY, ROY. Concrete Contractors, Foot of East Fifty-fifth Street, Cleveland, Ohio.

BLAKE, J. A. 268 Littleton Street, Wolcott, Ind.

BLAKELY, J. M. Concrete Contractor, 541 Union Street, Centralia, Ill.

BLAKESLEE CONCRETE BLOCK AND MACHINERY COMPANY. 408 Shultz Building, Columbus, O.

BLANC STAINLESS CEMENT COMPANY. J. Maxwell Carrere, General Manager, Allentown, Pa.

BLAW COLLAPSIBLE STEEL CENTERING COMPANY. Jacob B. Blaw, 407 Westinghouse Building, Pittsburg, Pa.

BLETHYN, BENJAMIN. Contractor and Builder, 1803 Oregon Avenue, Washington, D. C.

BOORMAN, T. HUGH. Filbert Paving Company, Pennsylvania Building, Philadelphia, Pa.

BORIE, JR., C. L. Borie and Zantzinger, 139 South Fifteenth Street, Philadelphia, Pa.

BOSSERT, O. N. 54 University Building, Milwaukee, Wis.

BOVEE AND SON, M. Concrete Contractors, Northville, Mich.

BOWER, VERNON D. Concrete Contractor, Main Street, New Trenton, Ind.

BOYER, EDWARD D. Cement Expert, Atlas Portland Cement Company, Catasauqua, Pa.

BOYLE, JAMES. Freeland, Pa.

BOYLEN, H. T. Buchanan, W. Va.

BOYNTON, C. W. Inspecting Engineer, Universal Portland Cement Company, Commercial Bank Building, Chicago, Ill.

BRACKER, KARL A. Vice-President, National Art Stone Company, 319 Superior Avenue, Dayton, O.

BRANNIN, ADDISON. Contractor, Aberdeen, Miss.

BRETT, ALLEN. Associate Editor, Concrete Engineering, 510 Caxton Building, Cleveland, Ohio.

BROCK BROTHERS MANUFACTURING COMPANY. Holden Brock, 3507 Olive Street, St. Louis, Mo.

BROWN, CHARLES CARROLL. Consulting Engineer, 408 Commercial Club Building, Indianapolis, Ind.

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"Cement Era."
"Cement World."
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Pekin	Jansen and Zoeller.
	Saal and Brooking.
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	Schmitt Construction Company, J. P.
Princeton	Illinois Gravel Company.
	Rubendall Brothers.
Rockford	Rockford Concrete Construction Company.
	Sawyer, W. W.
Rock Island	Concrete Construction Company.
	Robinson Construction Company.
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Springfield	Capital City Concrete Construction Company.
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Fort Wayne	Fort Wayne Cement Stone Company.
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	Dunlap, Simon L.
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	Watts, H.
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	Havlick, Robert F.
	Ideal Concrete Machinery Company.
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	Snell Manufacturing Company, R. Z,
	South Bend Machine Manufacturing Company.
Sullivan	Mankedick, Charles.
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	Pettyjohn Company, The.
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Blairstown	Everett, S. V.
Cedar Rapids	Neubauer, J. F.
Coon Rapids	Williams, L. B.
Creston	Kenney, E.
Des Moines	Marsh, J. B.
Estherville	Bingham, L. L.
Fort Madison	Downs, John.
George	Schoeneman Cement Block Company.

Goldfield	Shearer, James L.
Hampton	Sargent, G. E.
Keokuk	Brownell, F.
Oskaloosa	Carlon Construction Company.
Rock Rapids	Anchor Concrete Stone Company.
Sac City	Schaller, Philip.
Sioux City	Corn Palace Cement Works.
Walnut	Walnut Cement Stone Company.

KANSAS.

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Iola	Iola Portland Cement Company.
	Nicholson, George E.
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KENTUCKY.

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Madisonville	Lunsford, W. A.
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Bangor	Grady, William H.

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	National Hydraulic Stone Company.
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	Ruprecht Voirol Concrete Construction Company.
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	Turner Construction Company.
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	Warner, Henry P.
	Watson, Charles D.
Tonawanda	National Roofing Company.
Utica	Besch and Beebe.
Walden	Rosencrans, I.
	Rosencrans, W. S.
Warners	Empire Portland Cement Company.
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Westbury	Powers, Frank.
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	Stowers Charles A.
Alliance	Douglass, J. A.
Ashland	Ashland Steel Range and Manufacturing Company.
Ashtabula	Good, W. E.
	Johnson, Riley.
	Robinson and Company, M. C.
	Stanley, George L.
	Stockton, W. H.
Barberton	Nice-Rasor Company.
Batavia	Barr, J. L. H.
Bellevue	Bellevue Stone Company.
Broadway	Fogle, William S.
Brooklyn	Way, Raymond B.
Bryan	Neff and Son, B. F.
	Superior Cement Roofing Company.
Camp Perry	Parsons, O. B.
Canal Dover	Runyan Concrete Machinery Company.
Canton	Berger Manufacturing Company.
	Landor, Edward J.

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	Balantine, W. W.
	Barnum, F. S.
	Bicklehaupt, F. R.
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	Jeffrey Manufacturing Company.
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Fremont	Jackson, E. E.
Gibsonburg	Gibsonburg Coal and Ice Company.
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Kent	Kent Machine Company.
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Lima	Lima Artificial Stone Company.
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Uhricksville	Devine Concrete Company, The.

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West Park	West Park Block Company.
Willoughby	American Clay Machinery Company.
Wilmington	Compton, L. L.
Wooster	Central Construction Company.
Youngstown	Concrete Stone and Sand Company.
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	Davis, William R.
	General Fireproofing Company.
	Heasley, Veeder.
	Hunting, E. N.
	Youngstown Art Stone Construction Company.
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Zanesville	Hoffman, S. W.

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Ada	Whitaker, William L.

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Portland	MacNaughton, E. B.

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	Long and Mickley.
	Penn-Allen Portland Cement Company.
Altoona	Altoona Construction and Contractors' Supply Company.
	Standard Concrete Company.
Athens	Macafee Concrete Company.
Bellefonte	Bellefonte Lumber Company.
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Corry	Jones, Willard N.
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Derry	Harrold, E. W.
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Lancaster	Granite Concrete Stone Company.
Lansdale	Rosenberger, Oliver.
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Pen Argyle	Lynn, George V.
Philadelphia	American Cement Company.
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	Kirk, John L.
	Kramer, D. F.

Pittsburg	Pittsburg Testing Laboratory.
	Rader, R. H.
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Troy	Case, C. J.
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	Benson, Newton, D.
	Concrete Stone Company.
	Follett, F. B.

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Charleston	Southwestern Lime and Cement Company.

SOUTH DAKOTA.

Wessington Springs	Houseman, James A.
Woonsocket	Lind, E.
Yankton	Western Portland Cement Company.

TENNESSEE.

Chattanooga	Chickamauga Cement Company.
Decherd	Hayes, J. L.
Dyersburg	Hall, W. L.
Memphis	Miller Company, Incorporated, Charles R.
	Wright, S. M.
	Yarwood, Thomas.

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Dallas	Burns Byron M.
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	Stubbs, R. C.
El Paso	Frist Cement Company.
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Victoria	Welch, Charles J.

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VERMONT.

Rutland	Patch, W. E.

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Front Royal	Cook, H. L.
Norfolk	Gammon, A. S. J.
Richmond	Dunn and Fourqurean.
Rocky Mount	Virginia Concrete and Engineering Company.
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Port Washington	Ubbink, Joe.
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London	McArthur and Smith.
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Toronto	Beatty, J. C.
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Schneena, C. A.
Tipper, Harry.

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Florida	1	South Dakota	3
Georgia	6	Tennessee	6
Idaho	1	Texas	9
Illinois	107	Utah	1
Indiana	41	Vermont	1
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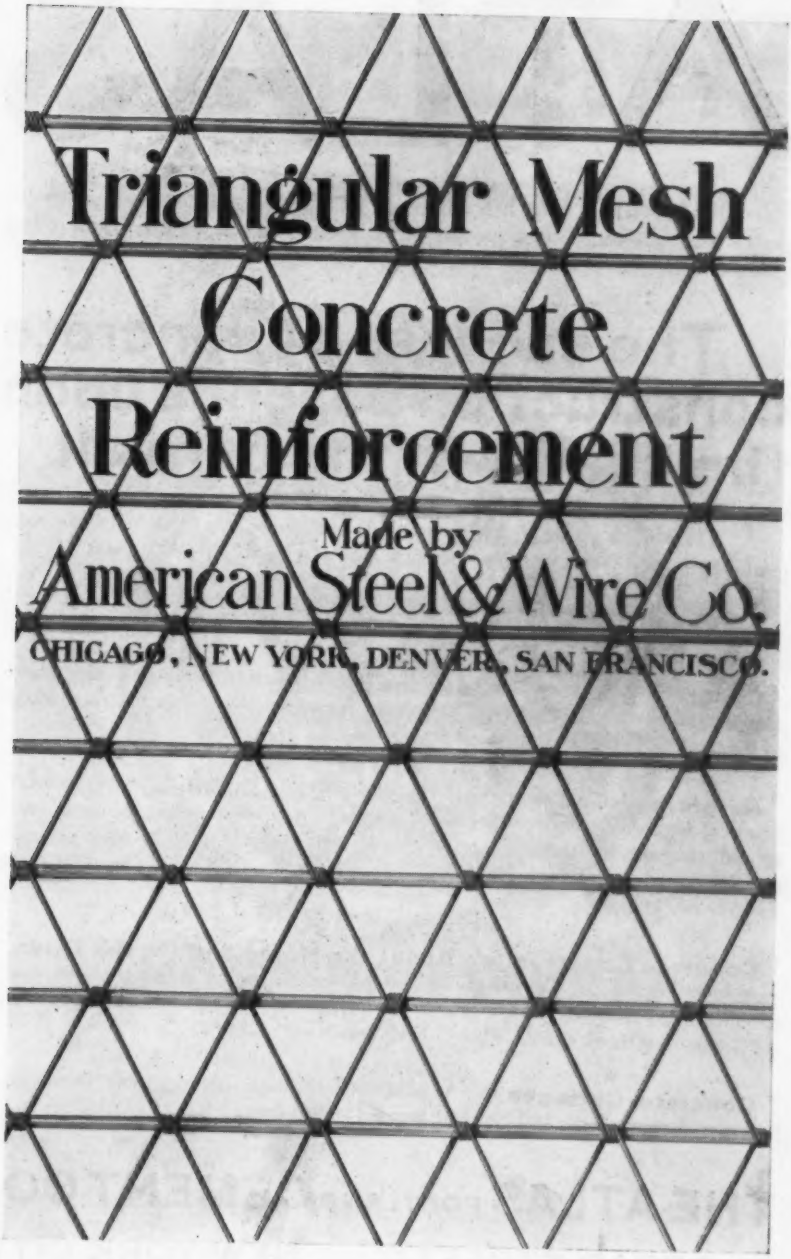
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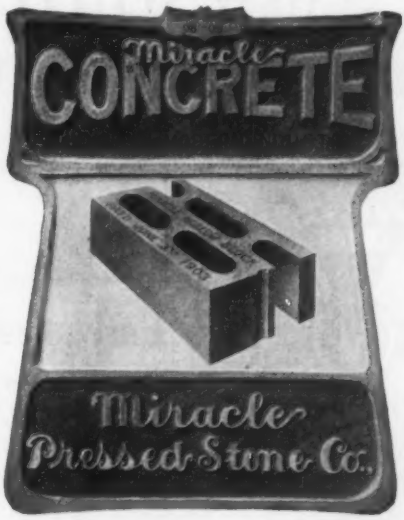

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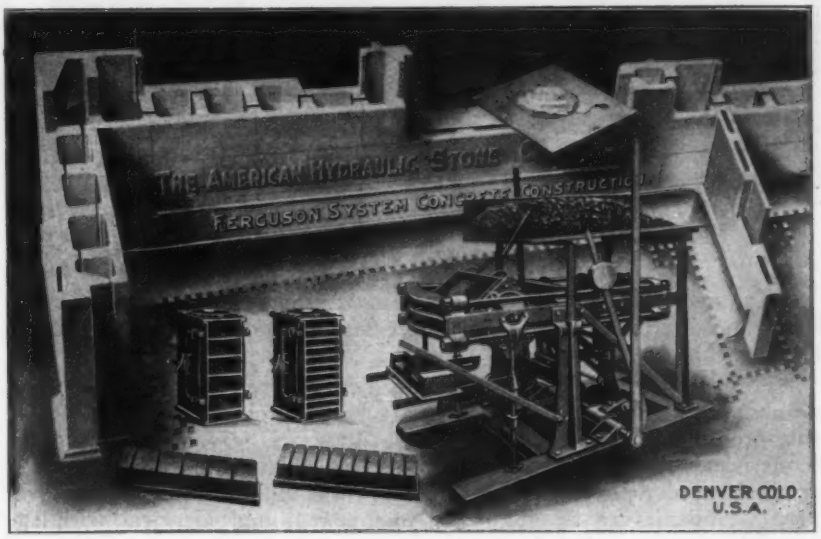

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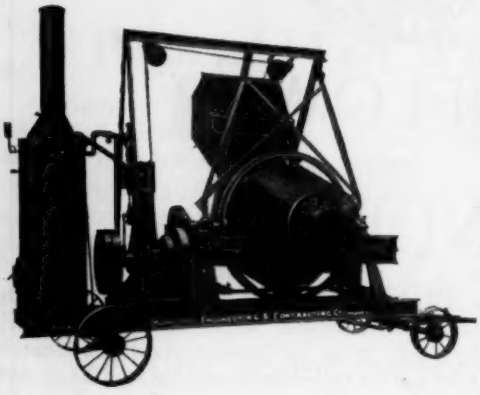

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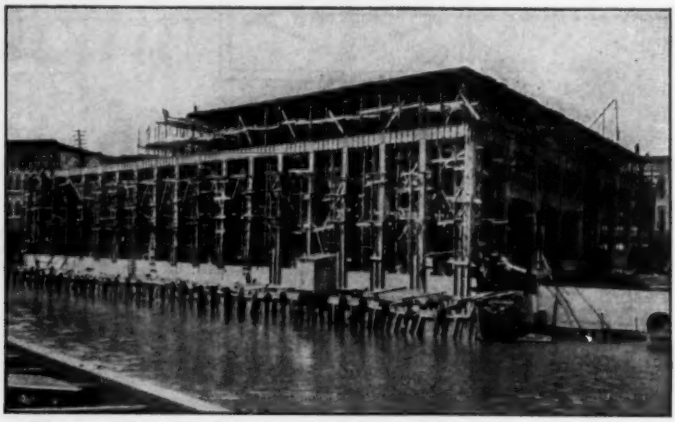

Above is an illustration of the Bostwick-Braun concrete warehouse, on the river front, at Toledo, O. Medusa Waterproof Compound used throughout foundations

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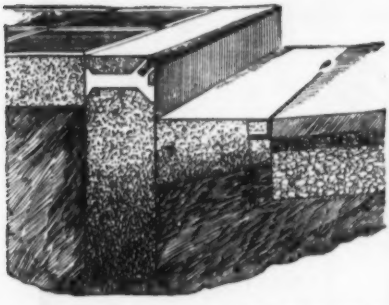

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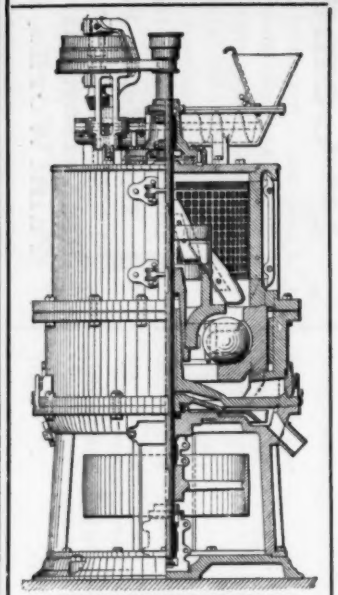

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